

JOINT FORCES STAFF COLLEGE
JOINT ADVANCED WARFIGHTING SCHOOL



Training Implications of the Tactical Aircraft Recapitalization

by

Gregory S. Keeton

Major, USAF

A paper submitted to the Faculty of the Joint Advanced Warfighting School in partial satisfaction of the requirements of a Master of Science Degree in Joint Campaign Planning and Strategy.

The contents of this paper reflect my own personal views and are not necessarily endorsed by the Joint Forces Staff College or the Department of Defense

Signature: _____

7 April 2008

Thesis Adviser: Michael Santacrocce, Col USMC

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD-MM-YYYY) 13 06 2008		2. REPORT TYPE Master's Thesis		3. DATES COVERED (From - To) 23-07-2007 to 13-06-2008	
4. TITLE AND SUBTITLE Training Implications of the Tactical Aircraft Recapitalization				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S) Major Gregory S. Keeton				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Joint Forces Staff College Joint Advanced Warfighting School 7800 Hampton Blvd. Norfolk, VA 23511-1702				8. PERFORMING ORGANIZATION REPORT NUMBER JFSC 25789	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release, distribution is unlimited					
13. SUPPLEMENTARY NOTES					
14. ABSTRACT With the perceived lack of a peer competitor to an air superiority threat, the US military's recapitalization of the tactical aircraft fleet has been greatly scrutinized. The F-22 and Joint Strike Fighter (JSF) have been vulnerable to a multitude of criticisms when viewed under the warfare experienced during or in Operations ENDURING FREEDOM and IRAQI FREEDOM. Within the current war construct, the incredibly high cost to the US Government for these aircraft programs will undoubtedly have a significant impact on funding dollars. This paper will analyze a portion of the background behind the purchase of these 'next generation' fighter aircraft and determine what implications upon combat operations and training will occur due to the fiscal constraints placed on them. Within this discussion will be the necessary inclusion of aircraft simulation to maintain high levels of combat readiness, and the ramifications this presents to aircrews due to training limitations. Lastly, the advantages and disadvantages of using virtual training in a combat airframe will be presented with analysis of why high fidelity simulators present a way ahead for training challenges.					
15. SUBJECT TERMS Fidelity, Simulation, Aircraft, Recapitalization, F-22, JSF, Training					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified	Unclassified Unlimited	70	19b. TELEPHONE NUMBER (include area code) 757-443-6301

Abstract

With the perceived lack of a peer competitor to an air superiority threat, the US military's recapitalization of the tactical aircraft fleet has been greatly scrutinized. The F-22 and Joint Strike Fighter (JSF) have been vulnerable to a multitude of criticisms when viewed under the warfare experienced during or in Operations ENDURING FREEDOM and IRAQI FREEDOM. Within the current war construct, the incredibly high cost to the US Government for these aircraft programs will undoubtedly have a significant impact on funding dollars. This paper will analyze a portion of the background behind the purchase of these 'next generation' fighter aircraft and determine what implications upon combat operations and training will occur due to the fiscal constraints placed on them. Within this discussion will be the necessary inclusion of aircraft simulation to maintain high levels of combat readiness, and the ramifications this presents to aircrews due to training limitations. Lastly, the advantages and disadvantages of using virtual training in a combat airframe will be presented with analysis of why high fidelity simulators present a way ahead for training challenges.

TABLE OF CONTENTS

Abstract.....	i
Table of Contents.....	ii
Introduction.....	1
Background.....	3
Training Shortfalls.....	21
Historical Fighter Aircraft Simulation.....	34
High Fidelity Aircraft Simulation.....	43
Conclusion.....	60
References.....	63
Vita.....	67

LIST OF FIGURES

Figure 1. Regression Flow Chart.....	25
Figure 2. F-15C Mission Requirements Table (INEXP/EXP).....	54
Figure 3. F-22 Mission Requirements Table.....	55

Introduction

Tactical Aircraft Recapitalization has become a heated topic in the United States Military's plan to transform itself to meet future threats to US interests. Specifically, the F-22 and Joint Strike Fighter have become targets for cost cutting measures in an attempt to save funds or transition funding options to what some consider more relevant defense programs. While this funding battle may never subside, this paper will accomplish a brief analysis on the rationale for inclusion of aircraft such as the F-22 and Joint Strike Fighter into the Department of Defense inventory. While the Joint Strike Fighter is yet to enter the United States Air Force, Navy or Marine Corps, similarities will be drawn between it and the F-22 program in order to gain an understanding of relevant issues that will be concurrent with both platforms in their future utilization and training scenarios.

Building upon the historically relevant information behind the progression of the F-22 and the future roles of the JSF, a change in training capabilities and strategies will be addressed. This is due in part to fiscal requirements in future military constructs that will require a change to current training in order to maintain a proficiency that has been maintained by fighter aircrews in the US military. The necessity of this adjustment will be made by examining the changes to current simulators in developing a fidelity that allows for accomplishment of tasks that were not available previously. A distinct challenge to the utility of simulation lies within the culture of fighter pilots across the department. Several other issues which have proven detrimental in the past are now able to be resolved and the hurdle of incorporating this training will be discussed.

Simulation itself may also prove to be a solution to the problem faced with a declining number of combat aircraft available to train a growing ground force.

Simulation is not a cure-all for the limited sorties allotted to fighter squadrons due to fiscal. There are still limits to the fidelity that a virtual aircraft can attain. However, more emphasis should be placed on them if the military continues down the road to recapitalization instead of procuring proven and cheaper aircraft to fill the gaps that are occurring today.

My thesis statement is that with current and future constraints on military budgets, the United States military's fighter force must become more dependent upon tactical aircraft simulation in order to maintain its superiority in combat operations.

Background

Few United States Military programs have been as polarizing to the Department of Defense psyche as the Advanced Tactical Fighter (ATF) program. From its inception, this program was seen to be extremely necessary by some within the United States Air Force and completely wasteful to others throughout the other services. The ATF program has become a love it or hate it affair with few entities who do not have strong opinions on the procurement of this airframe. The winner of the ATF program, the F-22 quickly rose to the pinnacle of controversial efforts by the Department of Defense to revitalize a military that was in the midst of transformation. Perhaps because of or in addition to the controversy caused by the F-22, additional aircraft procurement programs have faced increasing scrutiny in the battle for budget dollars.

The F-22 Raptor was developed as a replacement for the F-15C Eagle in a purely air-to-air, or air superiority, role and at the time had a development and procurement cost of \$99.1 billion (1993 year dollars).¹ This procurement cost included what the United States Air Force planned was a preliminary total of 800 airframes. At the timeframe of the F-22's inception, the cold war threat was still forefront in the minds of the military's key leaders. While the F-15 was still an incredibly viable platform, advances made specifically by Soviet fighters were making continued dominance of the F-15 questionable. The Advanced Tactical Fighter (ATF) program was initiated in 1981, with actual flight tests between competing aircraft design and manufacturers occurring in 1991. The eventual winner of this competition was the Lockheed F-22 (F being the alpha

¹ United States General Accounting Office, *Tactical Aircraft: F-15 Replacement is Premature as Currently Planned*, by Louis J. Rodrigues, Open-file report, United States General Accounting Office, Gaithersburg, MD, March 1994.

designator for fighter) and the US Air Force then made plans to acquire 750 aircraft to replace the F-15C as the primary air superiority fighter for the service.

Where the F-15C and similar aircraft such as the Russian MiG-29 and Sukhoi SU-27 are classified as 4th generation fighter aircraft, the F-22 has been designated as a 5th generation fighter due to its significant increase in capabilities. One shortcoming of all fighters is the amount of fuel that is able to be carried, which directly affects the amount of time that can be spent “on call” or within the window of vulnerability. Supercruise, the ability to achieve speeds above Mach 1.0 (the speed of sound) without using fuel-consuming afterburner provides the ability to remain on station for longer periods of time without having to refuel. Stealth technology and the low observable materials that construct the F-22 and JSF specifically deny the first-look abilities to any enemies, and that specific progression will most likely have placed the F-22 in a subsequent category. With that stealth technology comes the requirement to carry weapons internally, which places a limitation on internal fuel carriage as well as total weapons available to the pilot. Thrust vectoring and advanced maneuverability are also advantages of the F-22, and this aircraft is undoubtedly on top of the list of fighter aircraft throughout the world. However, the significant cost associated with this program will be problematic in the current environment of the United States budgetary process.

The Joint Strike Fighter (JSF), which has not received such defiant criticism as the F-22, was designed to replace aging fighters for the US Air Force, US Navy and Marine Corps. The aging fleet of F-18C and AV-8 aircraft of the US Navy and Marines has also been stipend by the purchase of the Super Hornet, designated the F/A-18 E/F, which was designed to replace the Navy’s conventional F/A-18C Hornet while providing

a stop-gap loss of the beleaguered AFX program which began in 1991. In a prescient move, the US Navy stopped the AFX program due in part to cost over runs but was faced with an attack force that was severely outdated with the Vietnam era A-6 Intruder. In order to save costs, the US Navy, Marines and Air Force combined resources in order to contract the JSF that would provide a common platform. This methodology, exemplified by the Vietnam era McDonnell Douglas F-4 Phantom program, provided cost sharing during development. Ideally, this shared platform process reduces cost sharing during development. This in turn, will reduce overall cost for the department of defense significantly by allowing for a common platform and additionally reduce maintenance and upgrade costs. The buy-in from three of the four services would provide a significant unifying front for the JSF program, but the sheer cost of a program that had many of the same criticisms of the F-22 program have placed it in jeopardy as well.

The JSF program as envisioned has also placed certain portions of the program in jeopardy. The Marine Corps specified a capability for V/STOL (Vertical/Short Take-Off and Landing) in order to be used on its short deck ships and as a replacement capability for the AV-8 Harrier. Recent changes in the structuring of the US Navy and Marine Corps have placed this capability at risk, and as such, have caused a significant portion of cost to be wasted. This same capability was specified by the United Kingdom in their portion of the Foreign Military Sales contract of the JSF. This premise will provide for inclusion of this capability. Foreign military sales of the Joint Strike Fighter has proven to be a significant reason for development of similar projects. The General Dynamics F-16 Fighting Falcon has become one of the most proliferated fighters of this era, and this is due in part to the feasibility of this airframe to fit into the defense posture of a

multitude of nations. While this airframe was not designed in cooperation with other countries, the rising development costs of such programs have made multi-national investment an important one requirement. The utilization of the F-16 by some twenty four individual nations has shown that foreign military sales plays a large part in reducing single nation investment toward these programs. Competition from such conglomeration programs, such as the Euro-fighter, has made multi-national interests a key in producing an airframe that is compliant with our coalition partners.

The cooperation of the services toward purchasing power has not proven to be completely successful. While significant cost savings may have been achieved by sharing some development costs, the continued scrutiny of need for such advanced fighter aircraft has still had an effect on the numbers of aircraft procured by the individual departments. As stated previously, the F-22 program was initially developed for 750 total aircraft. That number has been continuously adjusted and is now set at 381 aircraft for a total of ten fighter squadrons to fulfill the air superiority role.² While the 381 number is the requirement viewed as essential by the Air Force Chief of Staff and the Air Force Secretary, to date, only 183 aircraft have been authorized which leads to additional issues that affect the combat capability of the whole fighter force.³ For the JSF, or F-35 as it has been designated, the total procurement in 2001 was planned to be 2,852.⁴ Of this total, 1,089 were scheduled for delivery to the Navy and Marine Corps with 1,763 to be supplied to the Air Force.⁵ The Navy and Marine Corps have

² General T. Michael Moseley, "Air Force Gen. T. Michael Moseley Transcript, Part One," *Government Executive.com*, October 31, 2007, <http://www.govexec.com/dailyfed/1007/103107gg1.htm> (accessed November 30, 2007).

³ Ibid.

⁴ Global Security.org, s.vv. "F-35 Joint Strike Fighter (JSF) Lightning II Program," <http://www.globalsecurity.org/military/systems/aircraft/f-35-program.htm> (accessed November 30, 2007).

⁵ Ibid.

determined that the number of strike fighters required in the future may not be as high if they are reorganized to share platforms. In 2003, a reduction of planned number of operational strike fighters by 310 aircraft translated to a reduction of planned strike fighter procurement by 497 aircraft. This includes a reduction of JSFs from 1,089 to 680 (equating to a 38% reduction in procured assets).⁶ This reduction is thanks in part to a program known as the Navy-Marine Corps Tactical Air Integration Plan. In this plan, the Navy and Marine Corps will be managed more like a common pool of strike fighters, and in so doing, will reduce the costs associated with purchasing additional fighters for each of these services. This reduction may not be the end of cuts anticipated by the Department of the Navy. Continued budgetary pressure has forced the service chiefs to reconsider these costly programs and the numbers of aircraft that can be purchased as a direct relation to that budget.

In view of the current warfare construct, the need for replacement fighter aircraft has been seen by some as superfluous. This argument is bolstered by the extremely high cost that the F-22 and Joint Strike Fighter programs have demanded. The Air Force placed the F-22 as its number one priority in terms of acquisition and spent much political capital on obtaining this aircraft. The rest of the Department of Defense was not as enthusiastic for this program, however. The continuous battle for budget dollars placed the Air Force at odds with the US Army, Navy, and Marines for a significant amount of available funds with this program, and when cuts to the budget became a necessity, the F-22 program was a prime target. Of particular contention was the Department of the Army which was desperately seeking increased funding for the

⁶ Congressional Research Service, *Navy-Marine Corps Tactical Air Integration Plan: Background and Issues for Congress*, by Christopher Bolkom and Ronald O'Rourke, Open-file report, Library of Congress, April 10, 2003.

ongoing operations in OPERATION ENDURING FREEDOM (OEF) and OPERATON IRAQI FREEDOM (OIF). The battle that ensued has placed services at odds within the Pentagon, but also within the more conventional political arena. With a \$99.1 billion price tag, politicians could easily see a windfall with the adoption of this program should any part of manufacture occur within their constituency. Additionally, the capability of services to close unnecessary bases has been difficult due to the political significance that those bases present to the surrounding constituents. In fact, the most recent Defense Base Closure and Realignment Council (BRAC) ended up costing the Air Force \$1.8 Billion instead of actually saving money by consolidating bases for that service.⁷ Basing and government contracts provide a profitable incentive for procuring technological weapons. The ability of the Department of Defense to turn off such a profitable project would be difficult at best, especially with the steadfastness of the Air Force. In fact, in December 2007, several dozen lawmakers in the House and Senate signed a letter going out to Secretary of Defense Robert Gates asking him to continue production of the F-22 beyond its scheduled 2011 shut down date. The campaign in the house is led by Representatives Phil Gingrey (R-Georgia), whose district includes Lockheed's Marietta plant, and Kay Granger (R-Texas), whose district includes the Fort Worth plant where Lockheed Martin builds most of the aircraft's fuselage. Senator Saxby Chambliss (R-Georgia), is leading the campaign in the Senate and successfully pushed for a multi-year procurement of the F-22 in the past.⁸

⁷ General T. Michael Moseley, "Air Force Gen. T. Michael Moseley Transcript, Part One," *Government Executive.com*, October 31, 2007, <http://www.govexec.com/dailyfed/1007/103107gg1.htm> (accessed November 30, 2007).

⁸ Roxanna Tiron, "Defense Contractors, Allies on Hill press Gates to extend F-22," *The Hill*, December 12, 2007.

The feasibility of continuing without a replacement for the F-15C in lieu of Soviet advanced fighters, such as the SU-30, was examined in a recent exercise comparing these two airframes. This 2004 exercise, named COPE INDIA, placed the US F-15C against India's SU-30, Mirage 2000, and MiG-21 in a variety of aerial engagements. The superiority of the F-15C was in question based on the results of those engagements and was a strong argument for the updating of the combat aircraft in the US inventory. The results of the engagements are not a simplistic rationale for the purchase of an upgraded aircraft. While the aircraft capabilities in general terms may be similar or slightly weighted toward the Soviet type, the training of the pilots may be of more importance when comparing the two aircraft. Also of question is the intention of any state sponsored government that would be willing to take on the US military in terms of conventional weaponry, such as the current generation of fighter aircraft. The notion itself is one of the more optimistic arguments against the purchase of the F-22 and does in fact merit discussion. During Operation IRAQI FREEDOM, the Iraqi Air Force elected to bury their aircraft to avoid destruction of them, or merely did not fly them. Perhaps this was due to the superiority displayed by the US during Operation DESERT STORM where the Iraqi Air Force was greatly outmatched by the US Air Force, even with Iraq's MiG-29 and MiG-25 aircraft. The likelihood of a state versus state conflict in the immediate future can be seen by some as decreasing. This is in part due to the superiority exemplified by the US military during Operation DESERT STORM but also by the seeming vulnerability of the US military during Operation IRAQI FREEDOM.

Very few governments have the funds necessary to build or maintain a military force that is equal to that supported by the United States. That a true peer would emerge

is increasingly unlikely with the advancements made by the more advanced tactical aircraft of the US military. As such, there are multiple options available to combat such a superior force. One is to try and match the capabilities, which for most nations would prove to be too costly. Even if the country has the ability to purchase the required number of aircraft, they may lack the appropriate technological advances necessary to counteract the advances made by stealth technology currently available with the F-22 and in the future with the JSF. A second method would be to overwhelm a superior force with mass, or in this case with inferior airframes at a significantly higher number. This methodology is perhaps best exemplified by the North Korean concept of taking cheaper aircraft of great numbers and attacking or defending with these in the hopes of overwhelming the superior technological force. The third is to simply cede the superiority of the military and seek methods to use guerilla-like forces to defeat the enemy. This method may still be able to attack an advanced aircraft, or fifth generation fighter such as the F-22 or JSF, but not by methods which would counter the stealth capabilities of that aircraft. The preverbal “golden bb,” which is a single bullet shot that could cause enough significant damage to bring down a combat aircraft, would be a considerable loss of any multi-million dollar aircraft and pilot or crew. The loss of a F-22 to that type of threat would be incredibly damaging, first to the aircraft program and acquisition of future airframes but also to the US military as a whole. Perhaps more than damaging to the military, the coup that would ensue from a guerilla force that was able to destroy this high technology weapon system would perhaps be even more damaging in the recruiting possibilities that would occur.

Another example of the mass versus technology can be drawn from the Serbian shootdown of a US F-117 Stealth Fighter over Kosovo in 1999. On this fourth day of the air campaign, the previously invincible airframe was destroyed in an apparent barrage of SA-3 surface to air missiles.⁹ While tactics of the US and Serbs played a significant role in this incident, the fact remains that a cold war relic such as the SA-3 achieved what was previously thought to be unachievable—a shootdown of a stealth aircraft. The technological achievement of stealth technology was limited by transit routes and failures of other systems to determine the location of the specific SA-3 site. This mass over technology event will continue to present itself in future military conflicts.

The likelihood of the US military to use the F-22 against such an irregular enemy, which is the most prevalent in today's military paradigm is incredibly low. An argument can be made that the sensors available to commanders on the next generation airframes would provide valuable information in a non-traditional Intelligence, Surveillance and Reconnaissance (ISR) role, but the advantages come with significant risk. In an attempt to verify the utility of the F-22 in a counterinsurgency environment such as OIF and OEF, the Air Force took to ensure that it could be equipped with current weapons. Recent testing has been accomplished to outfit the Raptor with the Small Diameter Bomb (SDB) which was developed in part to adequately address engagement of small targets with a reduced area of collateral damage. The SDB specifically was requested to attack targets in a close contact situation or within inhabited areas such as Iraq or Afghanistan. The F-22 could be equipped with up to 6 of these precision munitions, but the question remains as to the utility of such a platform in this environment when less costly airframes are

⁹ Dr. Benjamin S. Lambeth, "Kosovo and the Continuing SEAD Challenge," *Aerospace Power Journal* Volume XVI, No. 2, (Summer 2002): 8-21.

available with sometimes superior firepower¹⁰. Additionally, non-kinetic effects, such as show of force passes and flare release, which have become prevalent during current operations, would place the F-22 in the heart of that golden bb arena. This risk is wisely being avoided, to the detriment however of the use of this airframe in the current war. This fact raises several questions. First, is the F-22 too expensive to be risked in combat? Second, is it too vital to the military to not be used?

Similar questions might be difficult to apply to the Joint Strike Fighter. The JSF was designed to replace aircraft that are currently being used in OEF and OIF to some measure of effectiveness. While arguments can be made that the cost associated with fourth generation aircraft such as the AV-8, F-18 and F-16 in this role is incredibly disproportionate to the threat, these airframes still provide strike capability and some non-traditional ISR capabilities. The cost of these fourth generation aircraft is comparatively low compared to fifth generation airframes. While the loss of an F-16 and pilot is not the only report framed by the news agencies in the US, it is a significant event that appears over multiple days in the reporting chain. The loss of a much higher dollar asset will undoubtedly bring further scrutiny and perhaps stricter rules of engagement on the battlefield. The F-22 might be used only against higher threat strike targets and the JSF may be similarly reserved based on risk to the pilot and airframe. This would produce negative effects for the ground commander who is often limited by the current number of aircraft available.

Current threats other than insurgent warfare are still relevant and the existence of countries with capable air forces such as Russia, China and North Korea warrant the

¹⁰ Jason Simpson, "Air Force Prepared to Field Small Diameter Bomb onto Raptor by 2011," *Inside the Air Force.com*, July 20, 2007, <http://www.OutsideDefense.com%20document%20F-22%20SDAM.htm> (accessed August 13, 2007).

continued demand for aircraft such as the F-22 and Joint Strike Fighter. While it may be easy to argue that any future adversaries would be foolish to take on the United States in aerial combat, the fact remains that there are aircraft, such as the SU-27 and MiG-29 that are sold to countries that do not hold the same ideological viewpoint on warfare as the United States. Venezuela, which has come to the forefront of US political engagement, is one such country that has recently delved into the fighter aircraft procurement party. President Hugo Chavez has made no qualms about his disagreement with the United States' policies and has recently purchased SU-30 fighters and has announced plans to purchase refueling aircraft.¹¹ The absence of a technological superiority would perhaps invite an enemy to take advantage of a perceived weakness in that arena. Conversely, the deterrent effect of a superior aerial force should not be disregarded in lieu of the lack of a perceived threat.

The potential threat posed by nations such as Russia and China must not be ignored in an attempt to save dollars or skew political power in the US military. The mere cost of the F-22 and JSF programs make them likely targets in an attempt to adjust for fewer and fewer available budget dollars, but recent events have shown that traditional cold war threats are not invalid. While the US has rightly focused on events in Afghanistan and Iraq, countries such as Russia have made attempts to show their continued military might and presence with flights of the long range bomber, the TU-95 "Bear," to Guam and around the British isles. Attempts have also been made by the Russians to improve weapons technology with the introduction of "the father of all bombs." In fact, since President Vladimir Putin took power in Russia, the defense

¹¹ Associated Press, "Venezuela to buy Russian-Made Planes," *The Boston Globe*, December 5, 2007.

spending of that country has quadrupled.¹² China has also shown the capability to wield a military that would challenge the United States should relations devolve over the straits of Taiwan. Chinese military spending doubled between 1997 and 2003, nearly reaching the level of the United Kingdom and Japan, and it continued to grow with an annual rate of greater than 10% during 2003-2005.¹³ Included in this increase in spending is the ability to produce its own version of the SU-27, known as the F-11A under a licensed co-production agreement with Russia as well as the use of the Naval and Fighter-Bomber variants of this aircraft¹⁴. Not only does China hold one of the more advanced air forces, it also has a modern air defense capability. Russia has provided China with the most up-to-date surface to air missile (SAM) systems. Stealth technology provides for a great deal of survivability of such radar systems and provides a strong argument for its inclusion in future product development.

The cost and necessity of the F-22 program has required rather significant restructuring of the program. Increasing costs of the program, as well as the F-15C's superb combat record, placed increased scrutiny on the requirement of the Air Force to replace one aging but capable fighter with a very expensive but more capable one. Additionally, the lack of a peer competitor in the air superiority regime gave opponents a significant point of weakness to the purchase of such an airframe. The breakup of the Warsaw Pact and the perceived Soviet threat has somewhat lessened the quantity and quality of the aircraft fighter threat. As costs for the F-22 increased and the fighter threat decreased, cuts were made to the program, primarily in the total numbers of aircraft to be

¹² Adrian Blomfield, "Russian army 'tests the father of all bombs,'" *The London Telegraph*, September 13, 2007.

¹³ U.S. Department of Defense, Office of the Secretary of Defense, *Annual Report to Congress: Military Power of The People's Republic of China 2007*, Open-file report, Library of Congress, May 23, 2007.

¹⁴ Ibid.

purchased. What began as 800 aircraft was subsequently cut to 442, then 381 and eventually to just over 180¹⁵. Through creative budgeting, however, the Air Force has still managed to adjust these numbers up an additional 60 aircraft by 2011¹⁶.

Perhaps in an attempt to quell the air superiority argument, the United States Air Force chose to enable the platform to carry air-to-ground weaponry and designated it the F/A-22 (F/A designating the aircraft as fighter and attack). This change in designation was not in name alone, and the ground attack mission that the F/A-22 would provide is a significant one. While performing a pure air-to-air mission, the armament load for the F/A-22 would be up to 8 air-to-air missiles which is equivalent to the current F-15C weapons load¹⁷. Currently, the surface attack weapons load for the F-22 is only 2 precision guided munitions with additional air-to-air munitions, enabling a multi-role capacity¹⁸. This load-out is similar or less than current generation aircraft, however, and is limited by the internal carriage requirements of low observability. This reduced number of weapons available for carriage places a significant degradation on the air-to-air capability and would better be solved by other methods of attack. Nonetheless, the change in name provides proof enough that a single purpose airframe such as the F-22, especially in a purely air-to-air role, was too tenable for the price that would be paid for such a capability.

¹⁵ John T. Bennett, "F-22 Raptors to Japan?," *Defense Industry Daily.com*, July 15, 2007, <http://www.defenseindustrydaily.com/f22-raptors-to-japan-01909/> (accessed August 14, 2007).

¹⁶ "Air Force signs multi-year contract for F-22," *Air Force Link*, August 8, 2007, <http://www.af.mil/news/story.asp?storyID=123063748> (accessed August 14, 2007).

¹⁷ Jason Simpson, "Air Force Prepared to Field Small Diameter Bomb onto Raptor by 2011," *Inside the Air Force.com*, July 20, 2007, http://insidedefense.com/secure/defense_docnum.asp?f=defense_2002.ask&docnum=AIRFORCE-18-29-16 (accessed August 13, 2007).

¹⁸ Ibid.

The change of name and role for the F-22 continues the current trend toward maximizing the capabilities of airframes that are available to the Joint Force Commander. This maximization of capabilities brings with it a reduction in singular purpose and perhaps a quality of employment. The dual role fighter has become a staple in the United States military, and this combined capability lends itself even more prolifically to the world's air forces. This trend is not purely a recent development. At times, necessity required that single-role fighters pick up a secondary or tertiary role due to the time or cost incurred by developing another singular purpose airframe. The frugality of the shared missions to single airframes lends itself nicely with the flexibility endowed upon aircraft especially in an environment where defense spending is tight. This concept lends itself to the very beginnings of air power itself as Douhet believed that the ideal aircraft would be the battle plane.¹⁹ The battle plane would provide a ground strike capability while being able to defend itself wholly against assault. The United States Air Force followed suit with the development of such an aircraft as the B-24 and B-17, which aided in the strategic bombing campaign during World War II. The German counter included fighter aircraft that quickly proved a formidable foe, and the allied fighters were subsequently equipped with longer range fuel tanks in order to provide longer range defense and fend off these assaults. The argument against multiple role fighters may not best be made with the World War II example, but instead with the successes made with single role fighters in current warfare. Perhaps the more successful airframes during recent engagements include single role fighter/attack aircraft such as the A-10, the AV-8 and F-15C. The A-10 remains an indisputable success as the best Air Force air-to-ground

¹⁹ Colonel John F. Shiner, "Reflections on Douhet, the Classic Approach," *Air University Review* Volume XXXVII, No. 2 (January-February 1986); 93-95.

and close air support aircraft in the current inventory. It is so successful that the US Army has essentially convinced the US Air Force to maintain it as an operational asset even though costs may seem to preclude it from tactical utility. The AV-8 enjoys similar accolades as a superior Close Air Support airframe available within the Marine Corps inventory. The F-15C, which is a purely air-to-air fighter, has the best kill ratio of any aircraft in history with 105 kills to 0 losses. While the single role aircraft may outperform the multi-role platform, perhaps the airframe itself is not the key. Perhaps it is the singularity of purpose that the training imbues upon the pilot of that airframe is the deciding factor in the success of those airframes. This will be discussed more below, but this dual role complexity may adversely affect the effectiveness of the F-22 as well as other multi-role airframes such as the Joint Strike Fighter. Specifically, the ability to maintain a training capability for a large number of events will be difficult to maintain as the roles required of an airframe increase.

Perhaps presciently, the Air Force Chief has recently narrowed the focus of the F-22. In October 2007, the F-22 and its pilots were to be optimized for two principal missions. Those missions include air superiority and the destruction of enemy air defenses (DEAD).²⁰ According to General T. Michael Moseley, the Air Force Chief of Staff, the F-22 being used for any mission other than these is wrong.²¹ This seems to be a reversal of policy for the F-22, and the mission creep associated with attempting to use this airframe in multiple other roles was spending modernization dollars or training sorties on the core missions of other aircraft. As previously mentioned, the F-22 was redesignated earlier in its lifespan to include the attack role but was then designated back

²⁰ Adam J. Herbert, "Every Pilot in His Place," *AIR FORCE Magazine*, October 2007, 66-67.

²¹ Ibid.

to F-22.²² This move will take quite a bit of that attack role from the F-22 and limit it to high risk, high intensity, high payoff missions against anti-access threats such as advanced surface-to-air missiles and fourth generation fighters.²³

Perhaps the most engaging argument for programs such as the F-22 and the F-35 are the increasing age of the airframes that currently compose the United States' tactical inventory. Modern combat aircraft were designed on what is termed a "damage-tolerance design philosophy."²⁴ This philosophy trades off performance of an aircraft for its durability to maintain an adequate balance of airframe lifespan. This premise allows designers to use structures that last only as long as they need to which determines design life. Aircraft such as the F-16 were designed to hold up to heavy stresses for 8,000 hours, which is now being prolonged to 12,000 hours. This change in lifespan requires additional dollars spent to determine what upgrades or maintenance is required to maintain these older airframes and to what end. Additionally, aircraft such as the F-16 were designed to be lightweight and less expensive but not to have a long life. The F-16 fleet currently has an average age of 17.1 years and has been plagued by age-related engine problems and metal fatigue in its airframe.²⁵

According to General T. Michael Moseley, the costs associated with older airframes are not easily calculated and the costs of maintaining older systems consume the investment potential for newer airframes. "Maintenance actions per flying hour go up; break rates per flying hour goes up; drives your supply counts up; takes time from

²² "F-22 Raptor, Air Force Fact Sheet," *Air Force Link*, January 2008, <http://www.af.mil/factsheets/factsheet.asp?fsID=199> (accessed January 3, 2008).

²³ Adam J. Herbert, "Every Pilot in His Place," *AIR FORCE Magazine*, October 2007, 66-67.

²⁴ John A. Tirpak, "The Aging of the Fleet," *AIR FORCE Magazine Online*, June 1996 <http://www.afa.org/magazine/june1996/0696watch.asp> (accessed November 30, 2007).

²⁵ Ibid.

your crew chiefs, time from your intermediate maintenance and flight-line maintenance. Your availability rates go down, your in-commission rates go down.”²⁶ All of these associated costs show that an increased amount of time and resources may outweigh the “value” anticipated by attempting to rejuvenate these older airframes.

The Air Force is not the only service that is having difficulties with the cost incurred by older aircraft. The Marine Corps is bringing older F/A-18 strike fighters out of reserve squadrons to replace newer version of the F/A-18C which have reached the maximum number of catapult launches and carrier landings. This has affected approximately 2,000 aircraft.²⁷ The US Navy has similar problems and the F-14 Tomcat was retired in 2006 due in part to the increasing costs associated with maintaining this older model aircraft.²⁸ Both of these indicate problems that were design limitations and recent problems with the F/A-22’s predecessor bring this issue to the forefront.

Recent accidents with the F-15C have placed the entire fleet on a downgraded status. This directly affects the air to air mission that these aircraft were produced for and in turn affects the combat posture of the US military. In 2002, an aircraft was destroyed and the pilot was killed during a high speed test run from Eglin AFB in Florida. After this accident, the Air Force concluded that the failure of a tail structure was to blame, and replaced vertical stabilizers on nearly half of the F-15 fleet after discovering that water intrusion was corroding the internal structure.²⁹ Even after these parts were replaced, airspeed restrictions were placed on the entire F-15 fleet. Those restrictions limited what

²⁶ General T. Michael Moseley, “Air Force Gen. T. Michael Moseley Transcript, Part One,” *Government Executive.com*, October 31, 2007, <http://www.govexec.com/dailyfed/1007/103107gg1.htm> (accessed November 30, 2007).

²⁷ John A. Panneton, “The Coming Crisis in Naval Aviation,” *Sea Power*, December 11, 2006, <http://www.military.com/forums/0,15240,120378,00.html> (accessed November 30, 2007).

²⁸ *Ibid.*

²⁹ Dave Montgomery, “An Aging Fleet has Air Force Worried,” *The Seattle Times*, March 5, 2007.

was a Mach 2.3 aircraft to Mach 1.5 and required an upgrade to all F-15s in order to alleviate that specific issue.³⁰ In November of 2007, the F-15 fleet was again grounded after the accident investigation of a national guard F-15 showed that a structural failure of a fuselage component caused another loss of an aircraft. This grounding made national attention as the F-15s were grounded for 18 days. 448 of the F-15 A through D models were grounded due to stresses imposed by high performance maneuvering.³¹ These groundings will undoubtedly continue but will not be limited to the F-15 community. In fact, mechanical issues occur rather routinely but the length and severity of this particular failure is significant. Both instances display the issues inherent with continuing to demand more hours on the airframes that they were not designed for. When originally designed, the F-15 was thought to have a design life of 4,000 hours.³² This was increased to 8,000 hours with more recent advances in material and design techniques, but the utilization of these aircraft exceeded what was originally anticipated. Because of the performance in the wars that the F-15 was designed for and the length of time flying in no-fly zones over Iraq in the 1990s, the F-15 has racked up hours more quickly than originally planned.

³⁰ Dave Montgomery, "An Aging Fleet has Air Force Worried," *The Seattle Times*, March 5, 2007.

³¹ James Dunnigan, "Robust F-18s Replacing Fragile F-15s," *StrategyPage.com*, December 14, 2007, <http://www.strategypage.com/dls/articles/2007121412911.asp> (Accessed November 30, 2007).

³² Ibid.

Training Shortfalls

The impact of program costs will be felt upon the services employing these weapon systems, especially in the training realm. With significant political pressure looming to end the conflict in Iraq, and the type of warfare encountered there, the quantity of funds to the Department of Defense will undoubtedly decrease. The decrease will most likely be felt deeply by the high cost, low utilization of the tactical aircraft programs, as well as the tactical aircraft fleets throughout the services. While the necessity of some level of force structure will undoubtedly prevail, the size and quality of that force will continue to be questioned. The US Air Force has already committed to counteract the reduction in F-22 aircraft with rejuvenated F-15Cs known as the “golden eagle” program. Within this program, the newer aircraft of this series will receive upgrades and will remain in use to supplement the F-22 in the air-to-air role. The Navy and Marines continue to use the F-18C and AV-8B, and with continued delays in the JSF, both the Navy and Marine Corps will be forced to continue using these aging aircraft and funding the repair of those airframes. The on-again, off-again A-10 program has received a recent upgrade, annotating the newer upgraded aircraft as the A-10C (denoting a significant upgrade to the previous airframe type). This is due to the close-air support role that the A-10 singly performs with such aplomb. The A-10 has also received a new lease on life with a continuation of this platform out to 2028.¹ Costly upgrades to this particular airframe are considered to be efficient since an adequate replacement is not in development.

¹ “A Higher-Tech Hog: The A-10C PE Program,” *Defense Industry Daily.com* August 28, 2007, <http://www.defenseindustrydaily.com/a-highertech-hog-the-a10c-pe-program-03187/> (accessed November 30, 2007)

How the services have dealt with financial difficulties in the past can provide a guide to future operational impacts that will be encountered in the near future. With continuing draw downs since the end of the cold war, services have slowly adjusted to the anticipated threat, and in so doing, have faced adjustments to the flying hour programs or funding toward those programs. These adjustments have varied from changes in roles, with specific emphasis on close air support and include additions to training programs, such as low-angle strafe events. While the funding available to older aircraft continues to dwindle, the funding available to train pilots and crew members in the new aircraft will undoubtedly be just as tenuous. With a smaller fleet of aircraft, as well as a smaller amount of money to maintain and train in those aircraft, it will leave a gap that will be felt across the services.

The results of funding reductions have in fact already begun. Following the publication of the Quadrennial Defense Review in February of 2006, Pentagon officials made plans to consider cutting \$15 billion to \$32 billion over the next five years.² As part of this cutting process the US Air Force is planning specifically on cutting the flying hours to operational squadrons in Fiscal Year (FY) 2008 by 13 percent³. This will effectively reduce the traditionally flown 300,000 flying hours per year to 270,000 hours per year. According to Col Eric Best, chief of Air Combat Command's flight operations division, these cuts are expected to last through FY 2013 and beyond.⁴ While this trend is not exclusive to the 2008 fiscal year, recent trends in flying squadrons have led to a

² Gopal Ratnam, "QDR May Devolve Into Budget-Cutting Recipe," *Defense News*, November 7, 2005, <http://aimpoints.hq.af.mil/display.cfm?id=7638> (accessed November 8, 2007).

³ Marcus Weisgerber, "USAF to Cut Ops Squadrons' Flying Hours Program 13 Percent in FY-08," *Inside the Air Force.com*, August 3, 2007, http://insidedefense.com/secure/defense_docnum.asp?f=defense_2002.ask&docnum=AIRFORCE-18-31-1 (accessed August 13, 2007).

⁴ Ibid.

shortfall in monthly training requirements in previous years. Air Force training requirements include a minimum number of training sorties or to complete a certain number of flying hours based on the aircraft platform. For fighter aircraft, the number of sorties accomplished per month is based upon a status of “experienced” for pilots who have met a standard for an upgraded level of competence, and a slightly higher number for “non-experienced” or less established aircrew. Air Force methods for determining the Readiness Aircrew Program, or RAP, are distinct for individual airframes but looking at the F-15 regulations regarding mission requirements provides a useful tool for analysis of these methods. By simplifying pilots into only squadron assigned pilots, and hence listing those as “combat mission ready” or CMR pilots allows for division into the experienced or non-experienced categories. To continue this example, non-experienced pilots are required to obtain 10 sorties per month to maintain this status. Referencing Figure 1 below from Air Force Instruction 11-2F-15 Volume 1, should a non-experienced pilot not meet his/her monthly requirement of 10 sorties, the three month total would be addressed in order to determine further action. The numerical requirement for the three previous month total is listed as 27 for non-experienced pilots. Should the pilot have attained 27 or more sorties in the preceding three months, they would maintain their mission ready status. However, if neither the one month nor three month totals are met, the squadron commander has the authority to place that person on a probationary status which would require that the pilot meet one month requirements. Should the one month requirement of ten sorties subsequently be met, the pilot is placed back on combat mission ready status. This sortie adjustment process could continue until the following month when/if that pilot does not make their prescribed ten sorties. According to Col

Best, the result of a lack of available sorties is, “...many more people who are not meeting the monthly requirements and they’re balancing that probationary period as a result⁵.” Effectively, the result is a one month on probation, one month off probation status. This on-again, off again practice minimizes a more serious status for pilots where they can be placed on a regressed status and require additional training to achieve the traditional “mission ready” status. The point is not lost however, that this may be a method of hiding the actual problem of a lack of quality sorties available to current fighter aircrew.

⁵ Ibid.

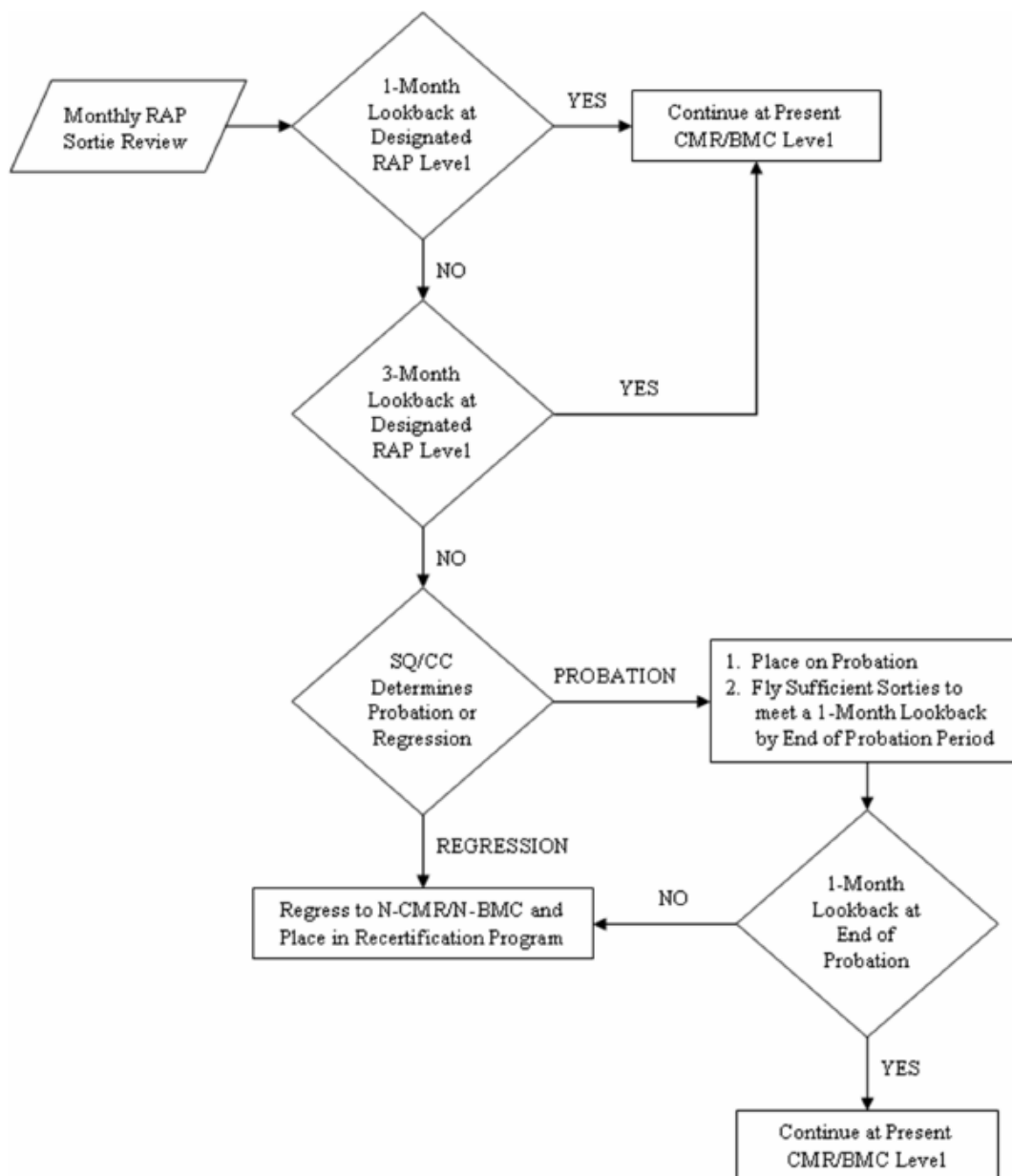


Figure 1. Regression Flow Chart

Added to the difficulties of maintaining pilots that are mission qualified is the ever increasing number of roles required of aircrew in the current warfare construct. Missions such as Defensive Counter Air are maintained while new mission such as non-traditional ISR (Intelligence, Surveillance and Reconnaissance) are continuously being added. As such the ability to maintain a level of proficiency in a multitude of required

tasks becomes increasingly difficult in a scenario where less sorties are available to aircrew. A decrease in the requirements for more traditional missions will allow for the incorporation of the missions required to support counterinsurgency operations, but the core capability to perform those traditional missions will continue to erode. If the argument is accepted that the US government must continue to perceive state versus state conflict as a threat, then some balance must be struck to allow for the training and capability of those missions. The high cost of the chosen platforms does not provide much flexibility for increasing the supply of pilots or airframes, while the roles they may fulfill continue to grow.

Funding the expensive platforms such as the F-22 and Joint Strike Fighter can prove difficult in an environment that does not place emphasis on updating an aging aircraft fleet, but the training of pilots to fly such aircraft can prove the more daunting task. As referenced above, this lesson seems to be one that is not easily remembered, or more accurately, it seems to be more easily forgotten. Following World War 2, the United States laid claim to perhaps the greatest trained air force in the world. The Naval and Army Air Corps pilots had extensive combat experience and the reduction in forces following the war undoubtedly played a role in reducing the capabilities of those pilots prior to the Korean conflict. More detrimental to the capabilities of the air forces of the United States was the lack of investment in aircraft. In the years following the 2nd World War, very little money was placed into maintaining a technologically superior fighter force, and the North Koreans were supplied with Soviet aircraft such as the MiG-15. The MiG was superior in performance to any aircraft that the US Air Force and Navy had in the combat zone until the F-86's introduction in November of 1950. It is difficult to

determine which side's pilots were the better trained as the MiG-15 pilots were most likely Russian, but the performance of the different aircraft is more readily compared.⁶ The overall number of American kills to North Korean kills amounted to a 10:1 kill ratio placed the emphasis of performance as the deciding factor on the capabilities of the different fighters. However, if analyzing only the Russian pilots versus American pilots, numbers such as a kill ratio of 2:1 in favor of the Russians have been annotated with the advantage being training and tactics.⁷

From the time of the end of the Korean War to the Vietnam War, the kill ratio continued to decline. Part of the rationale behind that was the loss of emphasis on Air Combat Tactics and the training of the pilots to perform that mission. Very few pilots from World War 2 or the Korean War were available for combat during Vietnam and the training available to them was sparse due to the emphasis placed on nuclear warfare. Between 1954 and 1962 the USAF training curriculum for fighter pilots included little, if any, air-to-air combat. This omission was partly a result of doctrine, which then regarded tactical fighters primarily as a means for delivering nuclear ordnance.⁸ As such the kill ratio dwindled to 2:1 in favor of the United States Military, but this decrease can be seen as one of the pieces that led to the development of improved training courses such as the US Navy's Fighter Weapons School, the US Air Force's Fighter Weapons School and RED FLAG exercises. All of these courses were designed to improve the capabilities and reality of training available to the combat air forces of both services in the goal to

⁶ Diego Zampini, "Russian Aces over Korea," *Ace Pilots.com*, September 2004, http://www.acepilots.com/russian/rus_aces.html (accessed 14 December 2007).

⁷ Ibid.

⁸ General Bruce K. Holloway, "Air Superiority in Tactical Air Warfare," *Air University Review* Volume XIX, No. 3 (March-April 1968); 2-15.

develop, refine and teach the tactical art of air combat maneuvering and hence improve the training across the services as a whole.

One of the similarities that these exercises has in common is the replication of airborne threats that improve the realistic nature of an aerial engagement. These aircraft that play the role of the enemy force are commonly known as “red air.” This term harkens back to the cold war when the red army would advance with its own red air force. The term continued to be used, and as friendly forces needed to be differentiated, the term “blue air” was adopted to name these friendly aircraft that were US or coalition aircraft. Inherent with the terms, however is a difference in employment during aerial engagements. The use of blue air versus red air is vital when practicing and planning for missions ranging from defensive counter air missions to large force employment packages on a strike mission. There are significant procedural differences in employment of these two types of air of which red air replicates Soviet-type tactics while blue air employs US tactics. The quality of red air replication varies and is based upon intelligence estimates of aircraft performance, weapons capabilities, and observed enemy tactics. Combining those three aspects into a red air force would be simple if the US were able to employ MiG-29s piloted by Russian trained pilots with the use of Russian command and control assets. This luxury has not often been available, and the cost associated with this methodology as well as the fact that we would be at a minimum familiarizing potential enemy forces with US tactics.

The opportunity to use actual adversary aircraft for this role as red air has presented itself in the past. In October of 1997, the United States acquired 14 Mig-29Cs, six Mig-29As, one MiG-29B, 500 air to air missiles and all the spare parts and diagnostic

equipment present at a Moldovan air base where the aircraft were stationed.⁹ These aircraft were partially dismantled, and the fighters were transported via cargo jets to Wright Patterson Air Force Base in Ohio, where the fighters were to be reassembled, analyzed and used for training purposes.¹⁰ Had the decision been made to use these aircraft as training platforms, numerous advantages would be apparent. However, this would require constant upkeep of the airframes and a group of pilots to be trained to fly these specific aircraft as well as upgrades to US military aircraft safety standards. The cost of maintaining these extremely accurate training aids outweighed the advantages gained.

In order to still utilize the valuable training aid of accurate red air, US forces are trained to replicate these Soviet-type tactics using US platforms and intelligence estimates. This solves the singular problem of securing US tactics and weapon capabilities from our possible enemies but brings up another problem. Now a US pilot or aircrew must be proficient on their system and tactics while still providing an accurate representation of a completely different and foreign airframe, tactics and weapons. This places a significant demand on training, specifically on air-to-air missions where blue air must have a red air threat to practice upon. Without red air forces, there are no targets to engage, simulate weapons engagement or make decisions to follow on maneuvering. In today's environment of continuing to improve, there are many missions where blue air would desire to have enough red air forces to outnumber their own blue air numbers.

The use of red air has varied in the past due in large part to budgetary constraints. Ideally, a dedicated group of pilots and aircraft could be used by the combat air forces to

⁹ Wade Boese, "U.S. Buys Moldovan Aircraft to Prevent Acquisition by Iran," *Arms Control Today*, October 1997, http://www.armscontrol.org/act/1997_10/moldoct.asp (accessed December 5, 2007).

¹⁰ Ibid.

accurately depict threat tactics, aircraft and weapons. The traditional threats could be narrowed to Soviet-type threats during the cold war, and tactics were developed to engage these enemies. As budgets were cut, so were the numbers of these forces, and the current availability of these professional “red air” forces are limited. Termed “aggressors,” the pilots were drawn from traditional fighter units to become subject matter experts in Soviet-type weapons and tactics. They employed these tactics as accurately as possible to train the blue air forces on appropriate actions and to display weapons threats for aircraft that would be encountered in Soviet-type maneuvers. While this displays the legacy of the cold war mentality, no better example existed for employing against what was the threat. The red air concept could be adjusted to different types of threats, as long as an accurate representation of capabilities (both weapons and tactics) was available to be incorporated.

As budget dollars were diverted, the aggressor program continued but in smaller numbers. The cost associated with deploying these units to multiple bases did not lend itself to budget savings, and the aggressors primarily were used as red air for Red Flag exercises and against the USAF Weapons School students while at Nellis Air Force Base for the USAF and the USN utilized them at its own TOPGUN school as well as a few land bases. A solution to the lack of full-time red air pilots and jets was to use squadron assets (both pilots and jets) to replicate the tactics and to serve as viable red air forces. In order to facilitate this, line pilots would at times serve as red air forces and use the same replication as the aggressor squadron as feasible in their own aircraft. Separate criteria were developed for each designated aircraft in terms of shot and kill criteria and sorties were allocated from the squadrons in order to fulfill a mission’s requirements. This

methodology allows for a superb capability to employ against an enemy threat but also decreases the number of blue air sorties available to pilots due to the requirement to fulfill red air missions.

Negative training also becomes an issue when using US aircraft in a red air role. As similar or identical aircraft are used as training aids, soviet type tactics can be replicated, but the systems on board coalition aircraft are often unable to replicate the enemy fighters' in terms of beyond visual range (BVR) identification methods. As an example, certain modes of the identification friend or foe (IFF) system on board US aircraft can be set up to interrogate aircraft of interest. If the specified code is not set in that interrogated aircraft, it can be identified as a foe, or this can be established as one step of a Rule of Engagement (ROE). Traditionally, more than just one step is required to determine a hostile aircraft. The aircraft radar can use certain modes to more accurately determine the type of aircraft being interrogated. As such, an F-16 would be identified differently than a MiG-29. While using US aircraft, negative training occurs when the F-16 is identified, but as part of the training ROE allowed to be fired upon if this is part of the hostile determination.

For clarification, consider a scenario when a four ship of F-18s (blue air) are fighting a two ship of F-18s (red air) and a two ship of F-16s (red air). In order to prevent a fratricide opportunity, the Rules of Engagement must be established to ensure that one of the blue air F-18s does not shoot at another of the blue air F-18s. If on board determination shows the aircraft being engaged is an F-16, that requirement is made (even though the blue air aircraft is still simulating a shot on an actual US aircraft). How does the blue air F-18 determine friend or foe after they and the red air F-18s merge?

Visual identification could be used for determination if the F-16 is recognized but not in the case of the F-18 versus F-18 scenario. Normal determination occurs with one or multiple iterations of radio calls which can often delay determination, and subsequently delay shots to neutralize the enemy aircraft.

This problem and others with target determination are not easily solved.

Aggressor squadrons often use Soviet-type paint schemes to replicate the enemy aircraft in order to assist in visual identification. As mentioned previously, however, these aggressor squadrons are in high demand and are not often available for training missions at home station locations. The BVR determination is often managed using an unrealistic ROE, however, and is becoming increasingly difficult to overlook. Limitations must then be levied upon the squadrons in terms of numbers of sorties to be allocated to red air sorties in order to obtain a higher level of training in actual US tactics. While some utility is gained from merely flying the aircraft, even in a red air role, the true benefit of tactics is minimized when not used in a blue air role. The ability to use some other method, such as simulation, is beneficial when considering the realism supplied to the training scenario.

Recently, Air Combat Command reviewed several courses of action that would address the need for red air for the F-22. The purpose was to provide potential options that would help to alleviate insufficient red air support for the F-22 Ready Aircrew Program (RAP) training.¹¹ One course of action was to reprioritize the aggressor squadrons in order to allow for more support from those squadrons. By changing this prioritization, however, a shortfall would occur in other training programs that also

¹¹ Joseph Holter, 2007. *Bullet Background Paper on F-22 Red Air COAs*. Paper presented at Air Combat Command meeting, Langley AFB, VA. October 19.

require the aggressor squadron support. This concept would amplify the problem already discussed above. Not only would a squadron be required to provide red air sorties, and subsequently reduced training, for its own pilots, but it would also be required to provide red air support for additional squadrons. This would effectively be employing additional units in an aggressor squadron role. This could be spread throughout the regular and reserve component in order to provide support platforms for red air. This would provide for specified red air for the F-22 but would be a trade off for the combat capability of the supporting squadron. Additionally, the cost associated with deploying those support units in order to spread the task out would be prohibitive.

A separate course of action looked at funding a civilian fighter aircraft program to support the Red Air requirements across the combat Air Force. While numerous civilian companies have provided proposals to Headquarters Air Force and ACC in the past, the ability to fund these programs is cost prohibitive. This would also directly conflict with the aggressor program in general. Using 'surplus' airframes is also limited as many of the aircraft that would be available are not viable. As an example, the T-38 companion trainers that could be used from units at Holloman AFB and Whiteman AFB have reached the end of their serviceable lifespan. All of these courses of action show advantages and disadvantages. However, one topic that was addressed was the use of a cost saving method in order to supplant the red air requirement of the F-22. That method was to use high fidelity simulation in order to alleviate some red air shortfalls.

Historical Fighter Aircraft Simulation

Aircraft simulation has provided a contemporary approach to solving a reduction in actual flight time, and in turn significant cost savings. While early simulators were crude and primarily used to practice aircraft switchology, or switch actuation, during emergencies or providing a platform for training for Instrument flying (simulation flying in weather), current simulators have a greatly enhanced capability. In fact, the ability to coordinate multiple simulators as well as integrating multiple platforms such as an Airborne Warning and Control System (AWACS) provides the ability to practice tactical situations in a virtual environment. This capability allows pilots and crews to link up across a secure connection from various parts of the world and participate in a virtual mission. So with this capability, should the leap be made to train purely on this medium, and if not how much training should be related to simulation? Therein lies a dilemma that is not easily solved. Simulation is undoubtedly a more cost effective method of training than actual flight. Few, however, would deny that actual flying time can be easily substituted by transition to a simulator, no matter what the fidelity. Simulation will need to make significant bounds in order to accurately replicate the physiological stresses that occur in actual flight conditions.

Military flight simulators have made significant advances in technological progression as have the airframes that they are used to replicate. The progression has not been directly correlated, however. Only recently have simulators reached a level of fidelity that allows for accurate tactical implementation. Part of the rationale behind a lagging simulator capability lies in the technological capabilities that were imposed upon the simulator platform. Aircraft simulation in earnest began in 1934 when the US Army

Air Corps became interested in the Link Trainer to improve pilots' skills.¹ This trainer was based on the vacuum operated mechanics used in automatic musical instruments which would inflate or deflate to cause an angular change in the relative pitch and roll axes and cause the trainer to simulate banks, climbs and dives.² Not ironically, these trainers were introduced at a time when the cost of flight was being questioned. Prior to the introduction of this trainer, most flight training was done via ground instruction from individual instructor pilots or in the air. Learning to fly was not only expensive, it was also dangerous and took a significant amount of time. In 1934, the US Army Air Corps was ordered to assist in the transfer of airmail due to mail fraud claims which were handled primarily by private contractors. The results of this takeover were a number of crashes that were costly in both human life and aircraft. This was attributed primarily to a lack of capability on the pilot's part in terms of night flying and instrument flying in the delivery of the mail.³

The concept of a military flight simulator came into more prolific use during World War II. During this time period, thousands of student pilots from all branches of the Service were trained on the ANT-18 Basic Instrument Trainer which was also known as the C4 or the "Blue Box."⁴ This joint simulator was very primitive but effective for its mission of training navigational skills and instrument flight training. Individual instruction was not divested from the simulator training, however, as an instructor was used to talk to the student through the simulator's radio system. Instrument flying was accomplished using the simulator's instruments which were operational and the

¹ *The Link Flight Trainer: A Historic Mechanical Engineering Landmark*, The Roberson Museum and Science Center, Binghamton, NY, June 10, 2000.

² Ibid.

³ Ibid.

⁴ "Link," *Wing Tips*, Summer 2007, The Vintage Flying Museum, Fort Worth, TX.

navigational course was transcribed onto a map throughout the process for review after the simulator mission.

Similar to the reasons for the inception of the Link Trainer, safety requirements and cost savings have been traditional causes for advancement in flight simulation. In 1976, the use of simulators for in-flight training and for emergency procedure received increased emphasis as a result of the high cost of fuel and the associated availability during the fuel embargo.⁵ Following the establishment of the Organization of the Petroleum Exporting Countries (OPEC), the increased cost of fuel caused military leaders to investigate methods to improve training available to aircrew in order to maintain a high level of mission readiness. This method would ultimately turn to the use of flight simulation to enhance instead of replace training.

Even though one of the consistent drawbacks to using flight simulation revolves around the term fidelity, fidelity of a flight simulator is not easily defined. There are several ways to separate different aspects of the fidelity of a system. For the purpose of this paper, simulator fidelity can be broken down into two separate categories. The first segment, objective fidelity, is the degree to which a simulator would be observed to reproduce its real-life counterpart aircraft in flight if all aspects of flight were sensed and recorded by a non-physiological instrumentation system onboard the simulator.⁶ In simpler terms, this could be relayed as the engineering viewpoint of fidelity. The second type of fidelity is referred to as perceptual fidelity and is defined as the psychological or physiological viewpoint and is the degree to which the trainee subjectively perceives the

⁵ Edward E. Eddowes and Wayne L. Waag, *The Use of Simulators for Training In-Flight and Emergency Procedures* in AGARD-AG-248 (Neuilly-Sur-Seine, France: Advisory Group for Aerospace Research & Development, 1980), 1.

⁶ *Fidelity of Simulation for Pilot Training* in AGARD-AR-159, (Neuilly-Sur-Seine, France: Advisory Group for Aerospace Research & Development, 1980), 1.

simulator to reproduce its real life counterpart aircraft.⁷ In simpler terms, this could be relayed as the pilot viewpoint of fidelity. While arguments could be made that perceptual fidelity must be nested within the objective aspect of fidelity, for the purposes of this analysis, they will remain distinct, but related.

Objective fidelity may be the easier of the two types of fidelity to replicate, but it is still lacking in several key areas. The ability to accurately represent the actual flight characteristics of a specified aircraft has reached a high level of realism. This is in part due to the manufacturers data when designing an airframe and the engine performance that is associated with it. In terms of engineering realism, the computing power associated with the generation of realistic algorithms required to accurately represent the unique and distinctive flight profiles that occur with specific airframes. While not perfect, the aerodynamic similarities to actual flight are incredibly realistic to include problems that are associated with the design. Departure from flight is an example of a scenario that is more difficult to replicate in the simulator. Due to slight variances in different aircraft, a difficulty in replicating certain flight profiles, and the slight difference in aircraft “feel” in the simulator, it is difficult to induce a departure in some flight simulators. As such, a negative transfer of training could be transposed. More on negative transfer of training will be discussed below.

The flight test phase of the ATF program and other similar competitions produces readily available objective fidelity to combat pilots. Due to the amount of valid information required by the competitors during these “fly-off” programs, a large amount of time and money is invested by the aircraft manufacturers to ensure that the airframe

⁷ *Fidelity of Simulation for Pilot Training* in AGARD-AR-159, (Neuilly-Sur-Seine, France: Advisory Group for Aerospace Research & Development, 1980), 1.

performs up to a specified level of capability. The most cost effective way for the business world to ensure this is to model the technology in a simulator. Due to this method, the objective fidelity is almost off-the-shelf in terms of availability in these aircraft. This aids in reducing the cost associated with developing a simulator that has the required amount of objective fidelity. While a government contract is then negotiated, the fact that the majority of code exists as the airframe is being produced not only saves time, but also dollars.

Perhaps the more difficult fidelity to raise to a sufficient level is the perceptual fidelity. This level of fidelity requires cues to be fed to the pilot at the appropriate time and in an appropriate sequence and all be linked into a contextual example proves to be difficult to achieve.⁸ While a complex mathematical model may suffice for the objective fidelity of the simulator, the ability to incorporate that model into one that the pilot recognizes and can interact with requires more than an accurate representation of flight characteristics. As mentioned above, while the true flight characteristics can be modeled, the ability of the pilot to replicate the aircraft feel may not be as simple as the replication attempts. The ability to replicate a departure scenario in a simulator may have significantly different “feel” than those sensory perceptions encountered in the actual aircraft. Sensations such as wind noise, aircraft buffeting sensations, and yawing motion all play a part in the perceptual fidelity of an aircraft. This does not even pose the two greatest issues facing fighter aircraft simulation.

Perhaps the two most difficult and important perceptual capabilities required for accurate fighter aircraft simulation are visual fidelity and motion sensory fidelity. In the

⁸ *Fidelity of Simulation for Pilot Training* in AGARD-AR-159, (Neuilly-Sur-Seine, France: Advisory Group for Aerospace Research & Development, 1980), 2.

past, these two items proved to be problematic at best to replicate. The first study to be accomplished on motion fidelity was reported by Jacobs and Roscoe in 1975.⁹ This study was very simplistic and dealt merely with a condition that would replicate a reduction in roll rate. While Jacobs and Roscoe found that the presence of motion may not increase simulator training effectiveness, a study by Fedderson in 1962 showed that simulators with motion may provide more efficient training.¹⁰ These early studies merely muddled the waters and did not address the sensory perceptions required to maximize the performance of an aircraft such as those in use in today's arsenal. The ability to replicate the environmental effects on the human body encountered in high performance aircraft are almost impossible. The typical number of G's, or amount of force applied to the body measured as a factor of the force applied by the gravitational pull of the earth, can reach up to 9 G's in flight. Obviously, since on earth people are experiencing a single G at rest, the ability to produce a constant force at nine times that would require a mechanism that would produce significant mechanical force. In order to replicate this condition now, the use of a centrifuge that is able to encapsulate a person is spun in a horizontal plane to produce a varying level of force and subsequent G. While the centrifuge is able to replicate the higher G, the issues involved with spinning the systems associated with a modern simulator are problematic. Additionally, the replication of higher G is achievable, but the effects of the spinning centrifuge wreak havoc on other physiological senses of the human body.

⁹ Paul W. Caro, *Some Factors Influencing Transfer of Simulator Training* in HumRRO-PP-1-76 (Alexandria, VA: Human Resources Research Organization, 1976), 7.

¹⁰ Paul W. Caro, *Some Factors Influencing Transfer of Simulator Training* in HumRRO-PP-1-76 (Alexandria, VA: Human Resources Research Organization, 1976), 8.

In previous simulators, an attempt has been made to somewhat replicate the higher G scenario through the use of lesser subsystems. These include but were not limited to g-seats, g-suits, stick shakers, and buffet/vibration systems.¹¹ Platform motion systems are included in some motion simulation capabilities but are not able to replicate the higher G associated with the performance aircraft as mentioned above. G-seats and G-suits are outfitted to inflate and impart a cue of g-loading to the pilot that they will experience in the aircraft during maneuvers. These force cues and those imparted by a device that would shake the stick or provide some buffet cue would only provide secondary information to the pilot.¹²

The ability to use motion systems as a primary source of replication has been seen as unnecessary or even unwanted. During instrument flight, the pilot is trained to fly only by use of instruments and to ignore force cueing information.¹³ However, during combat scenarios, these motion cues provide an ability to reach maximum performance of the aircraft without looking at instruments. In fact, the ability to use aircraft feel cues while maintaining sight of the enemy may be the deciding factor in a dogfight. As such, the ability to enhance the motion cues associated with flight simulation may prove to be the most difficult to achieve to a high level of fidelity.

Until the physiological considerations improve, simulation will continue to prove problematic to incorporate into a training curriculum. Pilots have resisted and most likely will continue to resist using a simulator that does not “feel” like the actual aircraft.¹⁴

¹¹ Edward E. Eddowes and Wayne L. Waag, *The Use of Simulators for Training In-Flight and Emergency Procedures* in AGARD-AG-248 (Neuilly-Sur-Seine, France: Advisory Group for Aerospace Research & Development, 1980), 14.

¹² Ibid.

¹³ Ibid.

¹⁴ Paul W. Caro, *Some Factors Influencing Air Force Simulator Training Effectiveness* in HumRRO-TR-77-2 (Alexandria, VA: Human Resources Research Organization, 1977), 53.

This can be blamed in part on the machismo persona that the military breeds into the fighter pilots, but also lies in the fact that a pilot's ability to perform lies beyond technical superiority with a system. This can be seen in the importance that basic flying maneuvers or BFM plays in the air to air scenarios. In part due to the exposure of aircrew to the physiological stresses such as Gs, altitude and stress from the realization that a mistake could result in death, a great deal of skill with the aircraft is found in flight rather than the simulator. With this emphasis on BFM, the next issue of perceptual simulation begins to become apparent. Current simulation capabilities include a level of visual cues that show significant improvement but is still not able to provide for some of the cues necessary for aircrew training.

According to Paul Caro, tasks that cannot be duplicated or even approximated in a device cannot be learned there for subsequent transfer to the aircraft. The ability to replicate the visual cues in a simulator has been studied quite a bit over the history of the airplane. One of the earliest studies used simple line drawings of a runway on a blackboard that was then tilted to replicate visual references to an aircrew. This simulation was shown to provide savings in aircraft time required to perform visual reference maneuvers on landing.¹⁵ As civilian technology progressed, so did the visual systems incorporated into flight simulators. In tactical aircraft simulation, a next step was some form of visual cues placed on a screen in front of the pilot. As computer technology progressed, the ability to use computer generated images became popular. Improvements in computer generated images has moved from a simple front mounted cathode tube display, to laser generated images on a dome theater to computer generated

¹⁵ Paul W. Caro, *Some Factors Influencing Air Force Simulator Training Effectiveness* in HumRRO-TR-77-2 (Alexandria, VA: Human Resources Research Organization, 1977), 39.

displays projected onto a small dome encompassing the pilot. These displays have limitations with each, and those limitations can have negative training effects upon the user.

Early studies involving visual flight training consistently demonstrated that instrument flight skills facilitated the acquisition of visual flight skills.¹⁶ These studies lacked the improved fidelity of current simulator technology and were perhaps introduced to show the current capability to use instruments to supplant training in the visual arena. To make up for the lack of visual capability in the virtual training environment, training was accomplished using video taped maneuvers or pictures. As computer technology progressed, the ability to produce animated representations also became a useful training tool to show a visual representation of the desired action. However, none of these methods were able to be utilized in a virtual environment where the visual cues were directly linked to the pilot's actions. The ability to improve the perceptual fidelity cues has always been addressed as a cost benefit issue. With more fidelity, cost increases, and what value does the visual improvement add? The answer lies in a basic learning process. Instructors may foster learning more effectively by arranging and sequencing the presentation of appropriate training environments than by use of training aids and devices.¹⁷ As such, the time may have come when the cost associated with producing a high fidelity simulator may in fact be worthwhile for training.

¹⁶ Paul W. Caro, *Some Factors Influencing Air Force Simulator Training Effectiveness* in HumRRO-TR-77-2 (Alexandria, VA: Human Resources Research Organization, 1977), 38.

¹⁷ Edward E. Eddowes and Wayne L. Waag, *The Use of Simulators for Training In-Flight and Emergency Procedures* in AGARD-AG-248 (Neuilly-Sur-Seine, France: Advisory Group for Aerospace Research & Development, 1980), 5.

High Fidelity Aircraft Simulation

The current level of simulation that is available to some combat aircrews has reached a level that can truly be defined as high fidelity. These simulators are part of what has been termed Distributed Management Training, or DMT. The DMT program is a readiness tool for warfighters that uses the advantages of simulation to better prepare aircrews for contemporary military operations. DMT has several mission essential attributes. One is that it be immersive in order to satisfy the training and rehearsal of mission essential competencies.¹ Cost effectiveness was not the only reason for incorporation of this simulation technology, however. “Safety considerations, mission complexity, airspace and range restrictions, real-world commitments, and cost limit the effectiveness of live flying training opportunities.”² In order to be immersive, the DMT system includes high fidelity simulators, simulations and models based on physical properties and interactions of the real-world counterparts. It also must be accessible to on-demand training and responsive to the daily training and rehearsal requirements of operational commanders.³ This program was initiated in 1997 as Gen Hawley, the Air Combat Command Commander, led an initiative to acquire a system of linked, interoperable high fidelity simulators that would replace the aging simulator fleet. Then, as now, funding for the program was difficult to justify. In December of 2000, the Chief of Staff of the Air Force granted permission to reprogram a limited amount of their

¹ U.S. Department of Defense, Department of the Air Force, *The Distributed Mission Trainer Roadmap: “The Next Generation in Air Force Readiness Training,”* by Grover Lollar, Open-file report, Defense Publishing Agency, 2001.

² Air Combat Command, Flight Operations and Training Division (HQ ACC/DOTO), *Concept of Operations for Distributed Mission Training*, 13 October 1998.

³ U.S. Department of Defense, Department of the Air Force, *The Distributed Mission Trainer Roadmap: “The Next Generation in Air Force Readiness Training,”* by Grover Lollar, Open-file report, Defense Publishing Agency, 2001.

fighter and ISR platform's flying hours in order to fund the program.⁴ This has resulted in a certain portion of events to be enhanced by simulator events. Only recently have these virtual events actually been used as replacement for actual flying events.

One of the first platforms to be incorporated into the Distributed Mission Training advanced simulation environment was the predecessor to the F-22. F-15C mission training simulators became operational in May 1999 at Eglin AFB and then at Langley AFB in July of that year. The F-15C simulators previous to the DMT simulator were limited to single ship training in emergency procedures or were placed in an environment where the other blue air were programmed without regard to the actions of the trainee. The only location that was able to address a multi-ship simulator environment was located at the F-15 factory in St. Louis, Missouri. This simulation facility, known as MACAIR (McDonnell Aircraft) combined two F-15 cockpits suspended in 40 foot domes that provided a nearly full field of view with two other simulator cockpits that were less sophisticated and had only video screens. While these simulators were all linked together, they were in high demand by all of the F-15 units throughout the Air Force. While the training was valuable, there were still limitations to the technology. During two detailed surveys conducted from 1988 to 1990, the Armstrong Laboratory (now known as the Air Force Resources Laboratory or AFRL) found that the pilots were confused by target aircraft color changes and found that it was difficult to determine aircraft aspect angle, tactical range or aircraft attitude.⁵ While these could be determined during actual flight, these problems made tactical formation a difficult

⁴ Department of the Air Force, Modeling, Simulation and Analysis Programs Division (AF/XOCA), *Background Paper on Distributed Mission Training*, by Russell Armstrong, August 18, 2001.

⁵ Michael R. Houck, Gary S. Thomas, and Herbert H. Bell, *Training Evaluation of the F-15 Advanced Air Combat Simulation*, report no AL-TP-1991-0047/AD A241675 (Williams Air Force Base, AZ: Armstrong Laboratory, Aircrew Training Research Division, September 1991), 13.

proposition and hampered mission effectiveness. Even with the problems associated with this simulator, the training accomplished was considered to be a tremendously valuable training tool that provided much needed training that was not available by other means. This simulator provided the capability to train in an environment that was no longer restricted to training to single-ship operations and could actually train in a multi-aircraft formation similar to the way they would actually employ.

DMT systems have addressed some of the shortfalls of previous simulators while building upon several of the advantages. While the physiological forces may never be addressed due to difficulties associated with the replication of such an extreme environment, the visual capabilities have been greatly improved over previous simulators. For the pilot of fighter aircraft, an encompassing shell of video screens closes around the simulator cockpit that replicates the switches and avionics systems of the actual aircraft. This gives a more realistic environment with almost 360 degree vantage point similar to that of the actual aircraft. Additionally, the graphics associated with the DMT are vastly superior to those of previous simulators due to the graphics programs that include accurate representations of threat aircraft and virtual landscapes. While the virtual displays are significantly improved over past simulators, they have not reached a fidelity that is close to the actual representation of these items. Improvements in technology will continue, however, and as these will undoubtedly continue to assist in developing this perceptual fidelity will continue to evolve.

Another key capability that the DMT system brought with it is the ability to review actions and reactions through the use of multiple playback functions for an in-depth debrief of the simulator events. While many simulators have had the ability to

produce valuable learning, the DMT system incorporates several strategies to enhance the amount of learning that is achieved. In traditional simulators, the ability to correct the student is often easier to accomplish in real time than in an actual flight situation.

Without a doubt, it is easier to reset and restart a simulation than a real flight due to coordination time and setup time required. However, many times the actual learning occurs in the debrief of the mission and mistakes will not be noticed until well after landing. This is accomplished during review of tapes that are recorded of cockpit sensors. This limits the review to instructor skill in recreating engagements from the limited recorded data or from memory and experience in order to replicate the actual scenario. Unfortunately, the video available is normally limited to two or three sensors. In the simulator, every piece of equipment is recorded to include all instruments, radar, radar warning receiver information, heads up display data, and even where the pilot is looking. This can be reviewed in detail after the mission or during the mission should the correction be made there. The time for setup of the engagements is minimal when compared to actual setup in the air, and as such, the amount of training that can be accomplished during a specified time period is greatly increased in the DMT environment. When utilizing multiple players in a combined engagement, the ability to rehearse or train to a multi-ship engagement becomes an integral capability of ‘training like you fight.’

The ability to combine or link simulators is one of the key linchpins of this technology. While the ability to link four simulators together in the MACAIR scenario was a key to the training that was able to be accomplished, the need to maintain a single aircraft capability was also important. DMT, which has transitioned into a term known as

DMO (Distributed Mission Operations), advances this capability by maintaining the ability to be used as a single-ship training tool for traditional simulator events. These include more realistic scenarios during emergency procedure training or instrument training. It also advances upon the MACAIR simulator by providing the capability to link beyond a single system or four-ship of fighter aircraft. This is accomplished through the interlinking of Mission Training Centers (MTC) across the globe. These MTCs can be individualized or interlinked to other MTCs or live entities when the mission requires.⁶ The constructive systems include war game simulations with adjudication of combat between participants. This addresses another issue encountered with actual live fly missions. As addressed earlier, the ability to differentiate between red and blue air players can be problematic. In the DMO system, red air players have all of the anticipated characteristics of enemy aircraft to include radar signature, electronic countermeasures and physical characteristics. This includes the “look” of the enemy aircraft and accurate threat weapons. Added to this, in the MTC, an operator may take control of an enemy aircraft to add realism to the scenario or change the programmed scenario should the situation warrant. The necessity of US personnel to fly red air sorties and miss out on valuable training opportunities is minimized, but the cost is a lack of actual instead of virtual flight time.

In today’s construct of military action, it is not simple enough to merely train within one’s own squadron or flight. In actual combat a multitude of additional aircraft or command and control entities will be involved. In order to accommodate this reality, the DMO program incorporates these different platforms into a training scenario. During

⁶ J. Michael Bower, “Distributed Mission Training,” *Military Training Technology*, online edition Volume 8, Issue 4 (November 19, 2003), <http://www.military-training-technology.com/article.cfm?DocID=272> (accessed December 28, 2007).

the inception of the DMT program, F-15Cs and E-3 aircraft were operational. In 2003, the first F-16 MTC came online at Shaw AFB.⁷ Currently the DMO program is able to support a large number of US Air Force platforms. Legacy platforms have been modified in order to be incorporated into this virtual environment with increasing success. The government contracting system has made incorporation a troublesome venture.

In the earliest days of DMT, a problem was encountered within the virtual environment due to a technical problem from two distinct platforms. During the engineering testing prior to the operational capability of the DMT environment, an interoperability limitation was encountered that degraded the training between the F-15C and E-3 AWACS simulators. The problem encountered was an incompatibility between the ability to interrogate the IFF (Identification Friend or Foe) between the two airframes. Effectively the E-3 aircrew were unable to properly interrogate friendly F-15s as required for them to train effectively.⁸ Upon investigation, it was determined that the approach toward accomplishing the IFF interrogation were fundamentally different and no amount of testing or debugging at the implementation level would resolve this dichotomy. There was no common conceptual model for the interaction, and as such, the implementation of the task was not compatible. This difference in implementation was due in part to a failure in a mission essential attribute of the DMO program. That being technical interoperability. The fact that two different contractors were used for the two simulators led to this issue with Boeing being the contractor used for the F-15C simulator and

⁷ Ibid.

⁸ Tony Valle and Bruce McGregor, "The DMT Master Conceptual Model," presented at the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC), 2004.

PLEXSYS supplying the AWACS simulation.⁹ Without a shared understanding of the standards required, interoperability issues such as this one will continue to be encountered. In order to resolve the issue, a common battlespace approach was required, and once that has been agreed to, a change in one or both of the simulators was required. Air Combat Command's DMO effort is nearly 100 percent contracted out with Wright-Patterson providing contract support and the standards for DMO.¹⁰ This does not bode well for incorporation into a holistic or joint attempt toward training the way the US military fights. With current warfare bounding more and more toward joint warfare, the ability to incorporate all services and even coalition partners into the DMO concept will be a requirement for success in the future. In its current state, with the Air Force as the lead for incorporation of this technology and training, the ability to provide consistent standards across the Navy, Marine Corps and Army will undoubtedly be problematic. The complexity to this is compounded even further by inclusion of different contractors as eluded to above. In order to alleviate interoperability issues, the Air Force has attempted to incorporate standards using a broader base of knowledge. The use of internationally recognized standards set forth by organizations such as the Institute of Electrical and Electronics Engineers (IEEE) and Simulation Interoperability Standards Organization (SISO) will aid in developing systems that are able to effectively interact.¹¹ However, when certain standards do not exist for the platforms within the Air Force inventory, the Combat Air Force (CAF) DMO uses another forum to develop standards

⁹ U.S. Department of Defense, Department of the Air Force, *The Distributed Mission Trainer Roadmap: "The Next Generation in Air Force Readiness Training,"* by Grover Lollar, Open-file report, Defense Publishing Agency, 2001.

¹⁰ J. Michael Bower, "Distributed Mission Training," *Military Training Technology*, online edition Volume 8, Issue 4 (November 19, 2003), <http://www.military-training-technology.com/article.cfm?DocID=272> (accessed December 28, 2007).

¹¹ Air Combat Command, Flight Operations and Training Branch (ACC/A3TO), *Distributed Mission Operations Combat Air Forces Newsletter*, December 2007.

protocol. That separate forum is the Standards Development Working Group (SDWG).¹² This working group meets once a month to discuss pertinent interoperability issues such as radios and communication, missile fly-out modeling, and weather issues. Once this new standard has been developed and vetted through the SDWG process and is adopted, it is then provided to the IEEE/SISO process for submission as an internationally recognized standard for all simulator communities.¹³ While the CAF DMO standards are not proprietary, the incorporation of the standards is vital for interoperability between not only Air Force systems, but also Navy and Marine Air systems. In the future, the interoperability of systems across all of the Department of Defense may be required, and this industry-wide recognized system will aid incorporation into the DMO process.

The issue of maintaining standards in this virtual training environment is prevalent today. Single airframe simulation does not seem to be affected by the standards issue, but the interlinking of airframes and assets is a key aspect of the training capability of this system. From December 12-14 2006, Air Combat Command sponsored an event that was labeled the Distributed Mission Operations Network (DMON) Realistic Airpower Virtual Event (RAVE).¹⁴ This event was designed to maximize unit to unit distributed training with minimal integration testing and minimal outside technical assistance and to showcase the DMO Network by assigning various bases to execute distributed events with each other throughout the Combat Air Force (CAF). Participants for DMON RAVE included all DMO network capable platforms plus several legacy platforms that were close to being DMON compatible. During the event, there were

¹² Ibid.

¹³ Ibid.

¹⁴ Air Combat Command, Flight Operations and Training Branch (ACC/A3TO), *Distributed Mission Operations Network (DMON) Realistic Airpower Virtual Event (RAVE) SUMMARY REPORT*, Langley AFB, VA, January 12, 2007.

several instances where standards compliance issues were noted. These primarily focused on red/blue air resolution and non-standard enumerations of flights that were placed within the environment. These problems will undoubtedly be resolved and other network issues that were present can be expected in this type of event. Issues such as multiple sites crashing and problems during reset or entering the network occur in the simplest networks, and a complex environment such as the DMON RAVE event will undoubtedly encounter such difficulties. As such, the ability to continue to build upon the DMON RAVE concept and incorporate linked systems into a more robust scenario is essential. The issue that was raised the most from operators in the scenario and from contract instructors was the lack of an administrative group to focus on the scheduling, scenario development, and the mission products required for such conjunctive scenarios.¹⁵ This concept is not new, and is in fact in use for large force exercises such as RED FLAG. While DMON RAVE was not designed to be an exercise or a FLAG event, it demonstrated the complexity and requirements on an event that encompasses a large amount of airborne assets.¹⁶ The support structure required to achieve “realistic” training is large whether it be an actual flight mission or one set in a virtual arena. Also, just as in any flight, the success of the event will depend on the quality and quantity of training achieved. Should the workload required to make it successful outweigh the benefits of the training, buy in from individual entities will be problematic. According to the conclusions of the DMON RAVE report, “Operators will not be motivated to plan for distributed events similar to live fly if the level of effort will exceed training gain.”¹⁷ This lends more credence to the incorporation of a “white” force that is available to aid

¹⁵ Ibid.

¹⁶ Ibid.

¹⁷ Ibid

in the development of scenarios and coordinate the inclusion of entities into the DMO network.

The issue of standards is not the only problem that needs to be overcome with the DMO concept. As mentioned previously, several inherent problems remain even in high fidelity simulation. In addition to the current limitations of visual systems and physiological replication capabilities, the airmanship skills that are acquired from actual flight are difficult to duplicate in the simulator. RAND research has shown that one of the reasons that Air Education and Training Command in the USAF has resisted replacing live sorties with simulator training in the formal training program is airmanship. The airmanship factors that were identified as difficult or impossible to simulate included heat, the fear of death from making a mistake, equipment failures, radio traffic, and pulling g's.¹⁸ While some of these can be replicated to a degree in a simulator, the volume of compounding difficulties that are often encountered in a flight situation and the complexity that evolves from factors that cannot be replicated accurately makes replacement of actual flight with simulation a serious threat to pilot morale.

The Chief of Staff of the Air Force has made his opinion clear on the increased use of flight simulators. Gen Moseley told members of the House Armed Services Committee that, "The notion that you can substitute simulator time for flying time...we have reached a limit."¹⁹ This comes on the heels of the Air Force's latest attempt to finance its procurement accounts by reducing live flight training exercises in favor of the increased use of simulators. As service budgets decline and the cost of actual flights

¹⁸ Marken, Taylor, Ausink, Hanser, Anderegg, and Wickman, *Absorbing and Developing Qualified Fighter Pilots: The Role of the Advanced Simulator* (Santa Monica, CA: RAND Corporation, 2007), 31.

¹⁹ Carlos Munoz, "Air Chief 'Not Comfortable' with Increased Use of Flight Simulators," *Inside the Air Force.com*, March 2, 2007.

increase, some sort of balance must be obtained. The real question is, what is the right balance of actual and simulated flying. Historically, the answer was that simulators would be used to enhance the actual flights, but the simulators would not replace any events required for training. That premise will need to change for the continued dominance of fighter forces across the military.

Air Combat Command is modifying the simulator program in order to fully integrate the training into the separate aircraft training programs. The traditional requirement for simulators was to accomplish one simulator event per month. The current intent is to incorporate stand-alone and DMO training into the Ready Aircrew Program as well as Air Expeditionary Force (AEF) spin-up training through Virtual Flag exercises.²⁰ This change in utilization of simulators can be seen in the most recent instruction for F-15C aircraft pilots. In previous version of this instruction, many mission types were not allowed to be accomplished in the simulator. This changed to a mindset that aspects of each mission “may” be accomplished in the simulator to the current direction which states that they “will” be accomplished in the sim. This is, of course, dependent upon the availability of this high fidelity simulator at the location of the unit. There are provisions in place for exclusion of sim requirements should the pilots not be collocated with the DMO facility, but the numbers now associated show a distinct change in policy toward using simulators toward maintaining currency in specified events. Figure 2 shows the requirement to utilize DMO simulators to train in events such as DCA (Defensive Counter Air), OCA (Offensive Counter Air) and TAC INT (Tactical Intercept) sorties. Noticeably absent from the list of included simulators are BFM (Basic

²⁰ Air Combat Command, Flight Operations and Training Branch (ACC/A3TO), *Distributed Mission Operations Combat Air Forces Newsletter*, December 2007.

Fighter Maneuvers) and ACM (Air Combat Maneuvering) which require a greater level of aircraft feel and visual fidelity than the other missions to accomplish proficiently.

MISSION TYPE	BAQ	BMC (NON-SIM Base)	AFRC BMC (N-10,15)	BMC (N-15)	CMR (NON-SIM Location)	AFRC CMR (N-10,15)	CMR (N-15)
DCA (N-11)	0	10/10	20/13	12/12	40/35	20/18	25/20
DCA RAP SIM (N-11)	0	0	5	8	(N-15)	5	15
OCA (N-8,11)	0	(/)	15/10	(/)	30/25	15/10	15/10
OCA RAP SIM (N-11)	0	(N-15)	5	8	(N-15)	5	15
TACTICAL INTERCEPTS	0	5/5	4/4	(/)	10/10	4/4	4/4
TAC INT RAP SIM (N-11)	10	(N-15)	4	5	(N-15)	4	6
ACM (N-14)	0	15/12	15/10	10/7	25/20	20/14	20/15
SHORT RANGE COMMIT RAP SIM (N-11)	0	(N-15)	0	3	(N-15)	0	5
BFM	0	10/7	12/9	12/9	25/20	12/10	25/20
AHC	2	2/2	2	2/2	2/2	2	2/2
INSTRUMENT	2	8/8	2	2/2	8/8	2	2/2
INSTRUMENT RAP SIM (N-11)	6	(N-15)	6	6	(N-15)	6	6
RED AIR (N-6)	(/)	(/)	(/)	(/)	60/60	50/40	60/60
CC OPTION (N7, 11)	60	80/66	40/40	62/48	10/10	25/10	10/10
TOTALS (INEXP/EXP/SIM)	64/6 4/26	130/110/0	110/90/2 0	100/80/30	210/190/0	150/110/20	163/143/ 47

Figure 2: F-15C Mission Requirements Table (INEXP/EXP)²¹

Specific Ready Aircrew Program (RAP) events may now be logged in conjunction with the RAP SIM missions annotated above. Specific limitations are however in place to ensure that the simulator does not simply replace the events that were originally required to be accomplished during live training sorties. Current guidance limits a majority of these events to 25% of the total requirement, but events that are consistently difficult to coordinate or accomplish in live flight may be given a higher percentage allowed.

²¹ Air Combat Command, Flight Operations Division (ACC/A3T), *RTM Air Force Instruction 11-2 F-15C Volume 1*, June 12, 2007.

How does this change in RAP simulator utilization transfer over to the newer platforms due to the Department of Defense? In order to analyze this topic, only the F-22 is available for comparison. Due to similarities in mission between it and the F-15C, this comparison should be advantageous.

Mission	BMC		CMR		ANG CMR	
	Inexp	Exp	Inexp	Exp	Inexp	Exp
AHC	3	3	4	3	3	2
DCA	()	()	20	15	16	12
OCA-ESCORT	()	()	23	17	18	14
OCA-SWEEP	()	()	12	10	10	7
OCA-DEAD	()	()	14	11	11	8
OCA-SURFACE ATTK	()	()	9	5	8	5
GLOBAL STRIKE (N-1)	()	()	3	3	3	2
ACM	10	7	18	14	15	11
BFM	10	7	14	10	12	8
RED AIR	()	()	60	52	48	39
INSTRUMENT (N/A ANG)	3	3	3	2	N/A	N/A
CC OPTION	94	80	20	18	16	12
Totals	120	100	200	160	160	120

Figure 3 : F-22 Mission Requirements Table²²

In comparing Figure 2 and Figure 3, many of the same missions are required of both platforms. Noticeably absent from the F-22 Mission Requirements Table however are any RAP Sim requirements. Additionally, the use of simulator training for the F-22 has been relegated back to use for Emergency Procedures or Instrument training events. The absence of these specific events is due to the lack of any high fidelity simulators in the F-22 community. This fact is troubling in that the trend in third generation platforms is toward using simulators to supplement the airborne training events. The rationale for such an obvious omission can be attributed to several causes. The first is the lack of funding toward the F-22 program from its induction into the Air Force inventory. In order to procure at a lower cost, and in turn more actual airframes, the purchase of DMO

²² Air Combat Command, Flight Operations Division (ACC/A3T), *RTM Air Force Instruction 11-2F-22A Volume 1*, June 15, 2007.

rated simulators for the platform may have been deemed too expensive. While this may be hard to believe in such a high dollar program, an additional rationale for their omission was addressed previously. The fighter/attack community, and in turn the leadership of those entities, feel that simulators do not provide the required training value for these airframes. In the coming days when budgets are constrained, yet missions required of the individual services may not decline, this thought process is perhaps out of date. There is no doubt that simulator training will not provide the same perceptual fidelity of an actual sortie, but the value of the training achievable may belay the cost associated.

In comparing the current training plans for the other services, the use of high fidelity sims in the US Navy shows some similarities to the US Air Force methodology. The US Navy has stated that it intends to use simulators to the maximum extent possible.²³ While this lends to the inherent utility of such training tools, there is still a seeing resistance to fully utilize the capabilities in lieu of actual flight training instead of virtual events. Simulators are not available to be used as a direct substitute for actual flying events in the Navy.²⁴ This policy is in place even though the Navy acknowledges the challenges facing today's combat aviation units. "The training required to master the employment of complex weapons systems, under extremely dynamic modern warfare conditions, is challenged by the realities of increasing aircraft age and operating costs as well as decreasing range and weapons resources."²⁵ This stark reality acknowledges the difficulties that will continue to plague the fighter communities, but the fact that virtual

²³ U.S. Department of Defense, Department of the Navy, *Commander, Naval Air Forces (CNAF) Instruction 3500.1B (Change 1)*, September 2005.

²⁴ Ibid.

²⁵ U.S. Department of Defense, Department of the Navy, *Commander, Naval Air Forces (COMNAVAIRFOR) Message, Navy Aviation Simulator Master Plan*, April 18, 2006.

events are not used to replace actual events only shows the momentum that must be overcome in order to incorporate this training tool.

The US Navy was forced to acknowledge the limitations imposed by the shrinking budget in previous cycles of the budgetary process. In February, 2006, the Chief of Naval Operations delivered a plan to Congress that would add ships to the fleet to reach a total of 313. The recapitalization of the Fleet required that training days and flying hours to support those days be cut to manage costs for the additional ships.²⁶ Flying hour funding for the Navy was cut in part in anticipation of Fleet Aircrew Simulator Training (FAST). The first of these FAST sims was the F/A-18C DMT simulators, similar to the F-15C simulators. For whatever reason, there are no DMO-type/FAST events in the current Training and Readiness matrices for any USN aircraft community. There are simulator events that can be accomplished and are termed sim-mandatory or sim-optional events. None of these events, however, are DMO-type events.

If the previous examples of the high fidelity simulators worth are not strong enough, the cost savings they display cannot be ignored. While the services struggle to validate the necessity of aircraft such as the F-22 and the F-35, the ability to maintain the proficiency of the aircrews that fly them will continue to be problematic. A cost comparison analysis brings perhaps the strongest argument for the utilization of high fidelity simulators. In an Air Combat Command analysis of separate airframes, the F-15C example is relevant to the argument. The cost for a single F-15 to fly a one hour sortie was averaged to \$14,796 in Fiscal Year 2006. The equivalent hour in the F-15C high fidelity simulator equated to \$584 per hour, but that cost was associated with eight

²⁶Department of the Navy, U.S. Fleet Forces Command, *Fleet Synthetic Training (FST) Navy Continuous Training Environment (NCTE) Concept of Operations*, April 30, 2007.

F-15C aircraft.²⁷ While this cost does not include the initial costs associated with the individual airframe, neither does the cost to operate the actual aircraft. With this comparison, in order to accomplish a mission where four live aircraft would engage four similar aircraft equals over \$118,000. Cost comparison alone shows that purely by the numbers, virtual training is 4% of the cost of an actual mission in this scenario.²⁸ Cost comparison does not provide the clarity that is required for such a decision, however.

Monetary valuation of the simulator is not the only aspect of the equation when determining the value of these high fidelity simulators. Add to this the fact that the simulator can be used almost exclusively for tactical training for that hour instead of a nominal 40 minutes due to administrative transit, and the value of that hour expands. As eluded to earlier, the simulator also provides for 100% blue air training. That is, no sorties must be expended in the red air role and can instead be used to focus purely on blue air tactics, techniques and procedures. In that comparison, the value of the simulator doubles in that actual flight events required eight aircraft while virtual does not require aircrews to perform the red air role in a reduced training role. If one begins to add in ancillary costs, virtual training continues to show the value that is inherent in this type of training. Costs associated with range time, adversaries, and munitions clean up, accumulate and make the cost differential even greater.

High fidelity simulators are not the cure-all for the budgetary woes for the combat aircraft of the services, however. The limitations listed above show that even the greatest fidelity achievable today will never truly replicate an actual sortie. The flight characteristics of an aircraft may be accurately represented for the typical aircraft in a

²⁷ Air Combat Command, Flight Operations and Training Branch (ACC/A3TO), *CFT-Cost Comparison Spreadsheet*, by Chuck Colegrove, presented in a brief at Air Combat Command, April 2005.

²⁸ Ibid.

simulator, but each jet is different in reality. One airframe may be slightly 'bent' and fly ever so slightly different than the others. The complexity inherent in today's fighter aircraft means that each jet behaves just a bit different. Additionally, each pilot has different abilities under the high stresses faced in an actual flight. Not only do g-forces play a role in aircrew performance but so does the pilot's aversion to risk. This aversion may mean that a pilot behaves one way in a benign situation such as the simulator and a different way in an actual aircraft. This reality means that simulators will never fully replace the training received during actual sorties. The use of high fidelity simulators does provide a crucial capability to enhance the training that occurs in actual flight. The utilization of these simulators should be increased in the instances where the training derived in the virtual environment will be beneficial to the aircrews, especially in today's fiscally constrained budget.

Conclusion

The end of the Cold War has placed burdens upon the US military that could not be accurately foreseen. While some may argue that the types of warfare that we prepared for against a Soviet-type threat would be incredibly difficult, engagement in Afghanistan and Iraq have shown that this insurgent type of enemy is more difficult. That is in part due to the fact that we had built a culture and a technological base to defeat the Soviet-type enemy on the battlefield and in the air. The development of the F-22 and Joint Strike Fighter are perfect examples of this capability. Both of these airframes are rife with technological capabilities that would undoubtedly best the threats presented by aircraft such as the SU-27 Flanker and MiG-29 Fulcrum. Unfortunately, the enemy that we are currently engaged in does not have the ability to employ in a manner that would allow for that match-up. This is not to say that no country will ever attempt to engage us in a 'traditional' sense. So the ability to overwhelm our enemies with technological capability has become both a strength and a weakness. The strength lies in our ability to engage state versus state with an advantage. The weakness is that we may not need to, and it is increasingly expensive to maintain these capabilities.

How then do we overcome this weakness? The answer lies in both the ability to maintain our capability but in a less expensive manner. The requirement for fiscal constraint will undoubtedly be levied upon the US military in the near future. Without the peer competitor that the Soviet Union played so reliably, the necessity for tactical aircraft recapitalization will continue to be a matter of disagreement between competing services in a fiscal dilemma. In order to maintain our advantage over other perceived threats, aircraft such as the F-22 and JSF must be acquired and maintained, but the

training allotted to the aircrew of these airframes will need to be adjusted. The adjustment should be made in the use of virtual training.

With the increased utilization of the simulator, care must be taken to ensure that the capabilities to maintain and repair the high-priced airframes remain in place. While the pilots receive excellent training from a simulator, the maintenance of the airframe and the training that takes place across the forces plays a vital role in ensuring the continued success of the complex systems. While computerized technology plays an ever increasing role in the modern generation of aircraft platforms, the technician that is able to properly diagnose and repair faulty systems is a skill that cannot fall from view. With a reduction of actual sorties comes a decrease in opportunities to properly identify and perhaps even locate significant deficiencies that exist in any new system that is adopted by the military. Significant thought should be placed on retaining the ability to identify problems and train forces to repair those faults when less and less time is spent in actual flight.

While virtual training should never fully replace actual flight training, the use of high fidelity simulators should be more openly embraced by the services that utilize them. Gone are the days when one could claim that the quality of simulator training is inferior to flight training. While it will always be different in some ways, in other ways it may actually be advantageous. The cost associated with provided red air as training aids in an air to air environment or large force exercise is incredibly high. The ability to replicate those threats has never been truly accurate and both of those deficiencies can be adequately addressed in the high fidelity simulators of today. The interconnectivity capability of these simulators provides for the ability to train as we fight. The joint

nature of the simulator environment will also allow for more seamless transition should we need to employ as a joint fighting force, but this capability needs to be embraced more fully by the services themselves. Without such buy-in, the inherent capabilities of these tools may never be fully realized.

High fidelity simulators are tools. They will never provide the training utility of an actual fighter aircraft. They do, however, provide a more cost effective training methodology that can be more fully utilized to enhance the few flight hours that an aircrew is able to achieve. Increasing roles and missions demanded of the counter-insurgency battles we are engaged in must be trained to. However, the US military must continue to train toward the state versus state missions that cannot be ignored. The high fidelity simulator provides a capability that we should be maximizing instead of trying to avoid. While the Air Force has begun to adopt this premise with the F-15C simulators, the F-22 simulators have taken at least one step backward. The Navy's incorporation of DMT simulators should also strive for greater incorporation into the training of aircrews throughout the fleet. Without the incorporation of these capabilities, the world's finest air forces may become more fragile in lieu of these highly capable airframes that are limited by the training that the pilots are able to receive.

As the United States military approaches a future that includes the threats posed by asymmetric threats as well as a more traditional, state based enemy, budgetary dollars will increasingly be tight. As such, the United States military's fighter force must become more dependent upon tactical aircraft simulation in order to maintain its superiority in combat operations.

Bibliography

- “A Higher-Tech Hog: The A-10C PE Program.” *Defense Industry Daily.com*. August 28, 2007. <http://www.defenseindustrydaily.com/a-highertech-hog-the-a10c-pe-program-03187/> (accessed November 30, 2007).
- Air Combat Command. Flight Operations Division (ACC/A3T). *RTM Air Force Instruction 11-2 F-15C Volume 1*. June 12, 2007.
- Air Combat Command. Flight Operations Division (ACC/A3T). *RTM Air Force Instruction 11-2F-22A Volume 1*. June 15, 2007.
- Air Combat Command. Flight Operations and Training Branch (ACC/A3TO). *CFT-Cost Comparison Spreadsheet*, by Chuck Colegrove. April 2005.
- Air Combat Command. Flight Operations and Training Branch (HQ ACC/DOTO). *Concept of Operations for Distributed Mission Training*. 13 October 1998.
- Air Combat Command. Flight Operations and Training Branch (ACC/A3TO). *Distributed Mission Operations Combat Air Forces Newsletter*. December 2007.
- Air Combat Command. Flight Operations and Training Branch (ACC/A3TO). *Distributed Mission Operations Network (DMON) Realistic Airpower Virtual Event (RAVE) SUMMARY REPORT*. January 12, 2007.
- “Air Force Signs Multi-Year Contract for F-22.” *Air Force Link*. August 8, 2007. <http://www.af.mil/news/story.asp?storyID=123063748> (accessed August 14, 2007).
- Bennett, John T. “F-22 Raptors to Japan?” *Defense Industry Daily.com*. July 15, 2007. <http://www.defenseindustrydaily.com/f22-raptors-to-japan-01909> (accessed August 14, 2007).
- Boese, Wade. “U.S. Buys Moldovan Aircraft to Prevent Acquisition by Iran.” *Arms Control Today*. October 1997. http://www.armscontrol.org/act/1997_10/moldoct.asp (accessed December 5, 2007).
- Bower, J. Michael. “Distributed Mission Training.” *Military Training Technology, online edition* Volume 8, Issue 4 (November 19, 2003). <http://www.military-training-technology.com/article.cfm?DocID=272> (accessed December 28, 2007).
- Caro, Paul W. *Some Factors Influencing Air Force Simulator Training Effectiveness* in HumRRO-TR-77-2. Alexandria, VA: Human Resources Research Organization, 1977.

- Caro, Paul W. *Some Factors Influencing Transfer of Simulator Training* in HumRRO-PP-1-76. Alexandria, VA: Human Resources Research Organization, 1976.
- Congressional Research Service. *Navy-Marine Corps Tactical Air Integration Plan: Background and Issues for Congress*, by Christopher Bolkcom and Ronald O'Rourke. Open-file report, Library of Congress. April 10, 2003.
- Department of the Air Force. Modeling, Simulation and Analysis Programs Division (AF/XOCA). *Background Paper on Distributed Mission Training*, by Russell Armstrong,. August 18, 2001.
- Department of the Navy. U.S. Fleet Forces Command. *Fleet Synthetic Training (FST) Navy Continuous Training Environment (NCTE) Concept of Operations*. April 30, 2007.
- Dunnigan, James. "Robust F-18s Replacing Fragile F-15s." *StrategyPage.com*. December 14, 2007.
<http://www.strategypage.com/dls/articles/2007121412911.asp> (accessed November 30, 2007).
- Eddowes, Edward E. and Wayne L. Waag. *The Use of Simulators for Training In-Flight and Emergency Procedures* in AGARD-AG-248. Neuilly-Sur-Seine, France: Advisory Group for Aerospace Research & Development, 1980).
- "F-22 Raptor, Air Force Fact Sheet." *Air Force Link*. January 2008.
<http://www.af.mil/factsheets/factsheet.asp?fsID=199> (accessed January 3, 2008).
- Fidelity of Simulation for Pilot Training* in AGARD-AR-159. Neuilly-Sur-Seine, France: Advisory Group for Aerospace Research & Development, 1980.
- Herbert, Adam J. "Every Pilot in His Place." *AIR FORCE Magazine* (October 2007): 66-67.
- Holloway, General Bruce K. "Air Superiority in Tactical Air Warfare." *Air University Review* Volume XIX, No. 3 (March-April 1968): 2-15.
- Holter, Joseph. 2007. Bullet Background Paper on F-22 Red Air COAs. Paper presented at Air Combat Command meeting, Langley AFB, VA. October 19.
- Houck, Michael R., Gary S. Thomas, and Herbert H. Bell. *Training Evaluation of the F-15 Advanced Air Combat Simulation*, report no AL-TP-1991-0047/AD A241675. Williams Air Force Base, AZ: Armstrong Laboratory, Aircrew Training Research Division, September 1991.
- "Link." *Wing Tips*. Summer 2007. The Vintage Flying Museum, Fort Worth, TX.

- The Link Flight Trainer: A Historic Mechanical Engineering Landmark.* The Roberson Museum and Science Center, Binghamton, NY. June 10, 2000.
- Lambeth, Dr. Benjamin S. "Kosovo and the Continuing SEAD Challenge." *Aerospace Power Journal* Volume XVI, No. 2 (Summer 2002): 8-21.
- Marken, Richard S., William W. Taylor, John A. Ausink, Lawrence M. Hanser, C. R. Anderegg, and Leslie Wickman. *Absorbing and Developing Qualified Fighter Pilots: The Role of the Advanced Simulator.* Santa Monica, CA: RAND Corporation, 2007.
- Moseley, General T. Michael. "Air Force Gen. T. Michael Moseley Transcript, Part One." *Government Executive.com*. October 31, 2007.
<http://www.govexec.com/dailyfed/1007/103107gg1.htm> (accessed November 30, 2007).
- Munoz, Carlos. "Air Chief 'Not Comfortable' with Increased Use of Flight Simulators." *Inside the Air Force.com*. March 2, 2007.
- Panneton, John A. "The Coming Crisis in Naval Aviation." *Sea Power*. December 11, 2006. <http://www.military.com/forums/0,15240,120378,00.html> (accessed November 30, 2007).
- Ratnam, Gopal. "QDR May Devolve Into Budget-Cutting Recipe." *Defense News*. November 7, 2005. <http://aimpoints.hq.af.mil/display.cfm?id=7638> (accessed November 8, 2007).
- Shiner, Colonel John F. "Reflections on Douhet, the Classic Approach." *Air University Review* Volume XXXVII, No. 2 (January-February 1986): 93-95.
- Simpson, Jason. "Air Force Prepared to Field Small Diameter Bomb onto Raptor by 2011." *Inside the Air Force.com*. July 20, 2007.
http://insidedefense.com/secure/defense_docnum.asp?f=defense_2002.ask&docnum=AIRFORCE-18-29-16 (accessed August 13, 2007).
- Tirpak, John A. "The Aging of the Fleet." *AIR FORCE Magazine Online*. June 1996.
<http://www.afa.org/magazine/june1996/0696watch.asp> (accessed November 30, 2007).
- United States General Accounting Office. *Tactical Aircraft: F-15 Replacement is Premature as Currently Planned*, by Louis J. Rodrigues. Open-file report, United States General Accounting Office. Gaithersburg, MD, March 1994.
- U.S. Department of Defense. Department of the Air Force. *The Distributed Mission Trainer Roadmap: "The Next Generation in Air Force Readiness Training,"* by

Grover Lollar. Open-file report, Defense Publishing Agency. Washington D.C., 2001.

U.S. Department of Defense. Department of the Navy. *Commander, Naval Air Forces (COMNAVAIRFOR) Message, Navy Aviation Simulator Master Plan*. April 18, 2006.

U.S. Department of Defense. Department of the Navy. *Commander, Naval Air Forces (CNAF) Instruction 3500.1B (Change 1)*. September 2005.

U.S. Department of Defense. Office of the Secretary of Defense. *Annual Report to Congress: Military Power of The People's Republic of China 2007*. Open-file report, Library of Congress. May 23, 2007.

Valle, Tony and Bruce McGregor. "The DMT Master Conceptual Model," presented at the Interservice/Industry Training, Simulation, and Education Conference (I/ITSEC), 2004.

Weisgerber, Marcus. "USAF to Cut Ops Squadrons' Flying Hours Program 13 Percent in FY-08." *Inside the Air Force.com*. August 3, 2007.
http://insidedefense.com/secure/defense_docnum.asp?f=defense_2002.ask&docnum=AIRFORCE-18-31-1 (accessed August 13, 2007).

Zampini, Diego. "Russian Aces over Korea." *Ace Pilots.com*. September 2004.
http://www.acepilots.com/russian/rus_aces.html (accessed 14 December 2007).

Vita

Major Gregory S. Keeton received his commission from the United States Air Force Academy in 1994 where he earned a Bachelor's of Science Degree in Aeronautical engineering. He attended Undergraduate Pilot Training at Sheppard AFB in Wichita Falls, TX. Upon graduation from pilot training in 1996, he was assigned to Eglin AFB, FL flying the F-15C, where he flew in support of both OPERATION NORTHERN WATCH and OPERATION SOUTHERN WATCH. Following this assignment, he was sent to Randolph AFB, TX to instruct Introduction to Fighter Fundamentals flying the AT-38B. During this assignment, he attended Squadron Officer's School at Maxwell AFB, AL. Following his AETC assignment, he returned to the F-15C at RAF Lakenheath, United Kingdom where he served as Flight Commander and Chief of F-15C Standardization and Evaluation. Immediately following that assignment, Major Keeton served as an operations staff officer in the Joint Center for Operational Analysis at US Joint Forces Command in Suffolk, VA. He is currently attending the Joint Advanced Warfighting School in Norfolk, VA. Major Keeton has been married to his wife, Lori, since 1994, and they have two children, Gregory and Timothy.